INTEGRATION OF A GIS AND AN EXPERT SYSTEM FOR FREEWAY INCIDENT MANAGEMENT

by

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(ABSTRACT)

Congestion due to traffic accidents and incidents can be reduced through effective freeway incident management. However, this is plagued by a number of problems and requires a high level of expertise and coordination among the involved personnel. The ill-structured nature of the problem, constantly changing conditions, the number of agencies involved, and the lack of current information often cause errors in decision and response. Under these conditions, there is need for computer based support tools to provide the required decision and information support and aid the entire process by improving coordination and communication.

This study focuses on addressing this issue through the development of an Expert-GIS system which integrates the powerful spatial data handling capabilities of a Geographic Information System with the rule based reasoning logic of an Expert System. The system is designed as a Group Decision Support System that provides the required support for both the substance of the problem (decisions) and the agency level interactions that take place. The ability to support the process of response is modeled using a blackboard architecture for the system.

The prototype developed fully integrates the software environments of Arc/Info and Nexpert-Object and presents a unified interface, from where different incident management functions can be accessed. A complete spatial database was designed for the Fairfax County

in Northern Virginia as a part of this development effort. Decision support is provided through a set of six integrated modules - incident detection and verification, preliminary response, duration estimation, delay calculation, final response plan and diversion planning, and recovery. Coordination and communication were enhanced by ensuring the uniformity of information at different locations using the system, and through a messaging mechanism that informed users about the current status of incident.

The prototype system was developed for two hypothetical agencies called the Traffic Management Center and The Police Control Center. Historical incident cases were use to test these systems and check the accuracy of the database and the rule base. Both the tests and the development effort showed a strong need for established sources of network information, that could be readily incorporated into the database.

Given the fact that the system works with real network data, the next phase of research in should focus on the deployment of the system at test sites. User feedback obtained from these tests would then serve as a basis for future enhancements.

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1. INTRODUCTION

Congestion on the nation's freeways is a serious and ever increasing problem. Once confined mainly to downtown areas, it has now become major urban/suburban concern. The important reasons for this include, higher rates of travel, lower vehicle occupancy and an increased use of freeways over arterials. In addition, random events like accidents, vehicle breakdowns and maintenance operations further aggravate the problem. The resulting congestion can be of two types - recurrent and non-recurrent.

Recurrent congestion is said to occur when the normal demand exceeds the supply for a relatively short time. This usually occurs during the peak hour, in all major urban areas and is quite predictable in both effect and duration. Non-recurrent congestion on the other hand is caused by random or unpredictable incidents that cause disruptions in the traffic flow pattern. These include traffic accidents, maintenance operations, temporary freeway blockages and even natural disasters. The overall focus of this study is on the non-recurrent aspect of congestion and how it can be mitigated through effective incident management.

1.1 THE PROBLEM

Statistics indictate that on a typical heavily travelled 6-lane urban freeway one can expect approximately 400 lane-blocking incidents, each year, for each ten miles of freeway [1]. When incidents occur, they not only delay traffic, but create additional safety hazards as drivers unexpectedly approach slow or stopped traffic. The direct costs associated with these incidents is as high as $100 billion per year. Unfortunately, incident occurences on the freeway system cannot be completely prevented. However, their impact on traffic can be controlled through effective freeway incident management.

Incident management refers to a set of strategies that are implemented to manage traffic flow and roadway infrastructure in the event of an incident. Typically it involves several agencies such as Traffic Control Centers, DOT's, State and Local Police, Fire, Rescue and Hospitals. The entire process aims at minimizing the the impact of an incident by:

- reducing the time for incident detection and verification
- reducing the response time
- exercising proper on-scene mangement of personnel and traffic
- providing timely and accurate information to the public

This process, however is plagued by number of problems and requires a high level of expertise and coordination on the part of all the agencies involved. The ill-structured nature of the problem, constantly changing conditions and the lack of current and accurate information inevitably cause errors in decisions and response. In addition, the number of agencies involved makes it very difficult to ensure coordination of actions and timely response to the incident. The problem is further compounded by the decrease in the human ability to process information under stress. Under these conditions, a major concern is the provision of computer based support tools for the personnel involved. The goal is to assisst the personnel with relevant information and decision support, and aid the entire process by improving co-ordination and communication.

1.2 BACKGROUND

Incident impacts and their mitigation has been the focus of active research at the Center for Transportation Research ar Virgina Tech for the past five years. Of significance is the use of effective mangement techniques to mitigate the problem. The research over this period has led to a better understanding of the process and its representation in terms of a framework for incident management and its various components.

1.2.1 INCIDENT IMPACTS

Incidents cause bottlenecks on the roadway, slowing down or even stopping the movement of vehicles. The degree of congestion caused by an incident depends on the type and duration of the incident, the number of lanes closed, and the volume of the traffic at the time. Figure 1.1 illustrates the effect of an incident on traffic flow. The flow past the incident is a fraction of the demand flow, and is a function of the number of lanes available and the type of incident.

When an incident blocks a traffic lane, it chokes the traffic flow and a queue starts building upstream of the incident. Blocking one out of three lanes can cut traffic flow by fifty percent and blocking two out of three lanes can cut flow by as much as eighty percent [2]. The vehicle hours of delay accrued by motorists in the queue is represented my the shaded area in the figure. This delay will continue to build until the incident is cleared and traffic flow is restored. If the normal flow of traffic is reduced by diverting to alternate routes, then the vehicle hours of delay is minimized (shaded area in the figure). The hatched area shows the additional delay accrued if the normal flow is not diverted.

Once the incident is cleared, the queued up traffic clears the clears the incident site by utilizing the extra capacity. But the getaway flow is limited by the maximum capacity of the roadway. On a congested urban freeway, an incident can dam up a huge reservoir of vehicles, and it may take an hour or more after the incident is cleared to dissipate the accumulated traffic.

1.2.2 THE INCIDENT MANAGEMENT PROCESS

Incident management refers to a set of strategies and the coordination of activities undertaken by one or more agencies to manage traffic flow and roadway infrastructure in the event of an incident. A well organized and coordinated incident management operation will assure delivery of appropriate and efficient service, thereby reducing the cost of the incident in terms of delay and wasted fuel. Congestion caused by an incident can be minimized by

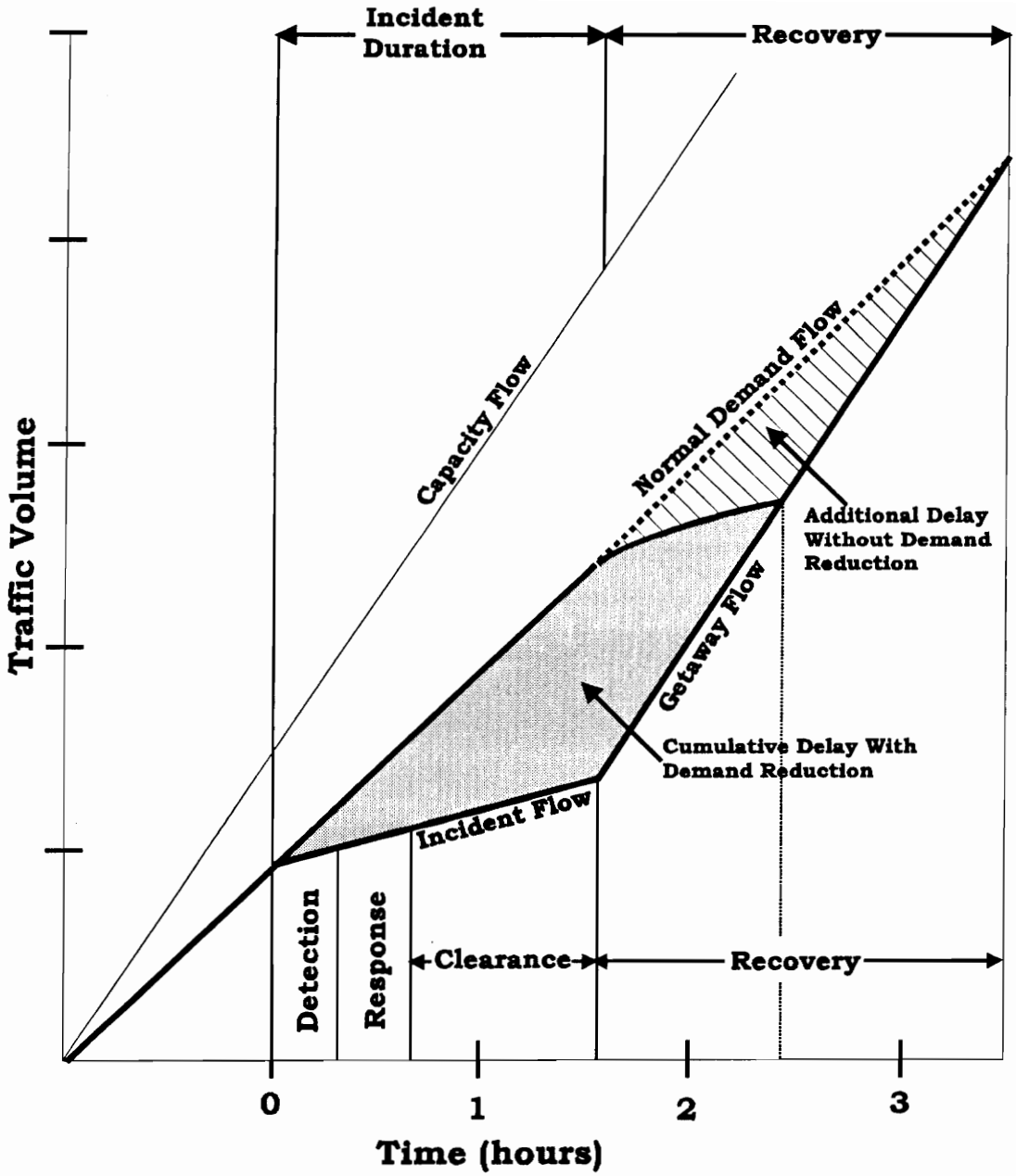

Figure 1.1 - Traffic Flow During an Incident.
(Source: University Center for Transportation Research, Virginia Tech., Wide Area Incident Management Expert-GIS System Development, Project Progress Report, July 1994.)

clearing the incident as quickly as possible and diverting traffic before more vehicles are caught in the incident queue. The entire process consists of four sequential steps: incident detection, response, clearance, and recovery (Figure 1.2). The general state-of-practice in implementing these four steps is as follows:

- **Detection:** Most major incidents are detected within 5-15 minutes; however, minor ones may go unreported for 30 minutes or more. An estimated one-third to one-half of reported incidents are detected by routine police patrols or other service patrols. The rest are reported to police from roadside call boxes, over citizen-band radio, and from cellular phones. A dozen calls or more might be triggered by a major accident. Wire-loop detectors installed in the pavement, are also employed to monitor traffic flow. Many tunnels, bridges, and highly congested urban highway corridors are monitored using closed-circuit television cameras, which can be used to detect incidents.
- **Response:** The police have the responsibility to confirm the incident, assess what needs to be done, and summon help as needed. Police dispatchers commonly handle communications about an incident, but increasingly, traffic management centers are coming up in many cities to coordinate traffic and incident communications. Most urban areas have emergency response plans for catastrophic incidents, especially those that involve hazardous materials. Some areas have traffic diversion plans for major incidents. Traffic management teams involving state and local police and highway engineers are becoming popular ways to develop response plans and traffic diversion routes.
- **Clearance:** A majority of freeway incidents are cleared by private tow-truck operators. The police officer on the scene diagnoses the problem, decides on what kind of towing equipment is needed, and oversees the operation. Most police departments have formal or informal rotation lists of tow-truck operators and distribute work among them.
- **Recovery:** Recovery consists of three steps - restoring traffic flow, preventing more traffic from building up at the incident, and preventing the congestion from spilling across to the metropolitan traffic network.

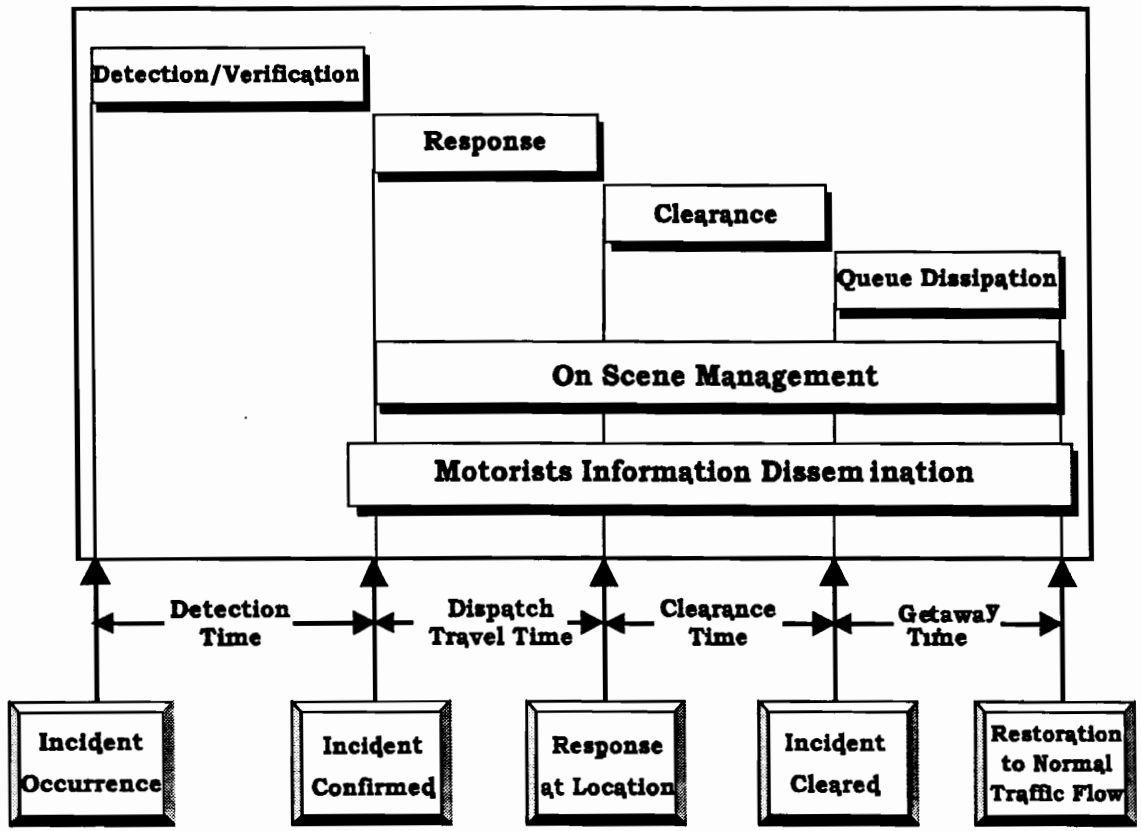

Figure 1.2 - The Incident Management Process.
(Source: University Center for Transportation Research, Virginia Tech., Wide Area Incident Management Expert-GIS System Development, Project Progress Report, July 1994.)

When an incident occurs, various agencies respond to the incident. An efficient incident management process is one where all involved agencies coordinate their operations to minimize congestion and delay caused by incidents. Typically an incident is detected by any of the following agencies: highway patrol, city or state police, DOT, or aerial surveillance crew. When an incident is reported either by commuters or by one of the above mentioned agencies, it has to be verified by the police or sometimes by private agencies such as verification patrols. Depending upon the type and severity of the incident, various other agencies are called in. In the case of disabled vehicles, the police usually call in tow-truck operators to clear the vehicle. If it is an accident with injuries or fatalities involved, fire and rescue units and Medvac units respond, along with tow-truck operators. Incidents involving trucks carrying hazardous materials require a hazardous materials management team or the environmental protection agency to respond to the situation. If any of the roadway structures are affected by the incident, structural engineers are called upon to inspect and determine damage to the structures. The entire effort is often coordinated by DOT officials or a centrally located traffic management center.

1.3 RESEARCH OBJECTIVES

The various steps discussed above have to be coordinated in a parallel non-sequential fashion. Based on the type, nature and severity of the incident a number of actions have to be taken. These include, identifying the agencies and the resources required to respond, selection of alternate routing plans if necessary, and dissseminating information to the public. In addition, there is a need to accurately predict the duration of the incident, determine if diversions are necessary, and continously update and modify existing plans based on the changing conditions at the incident site.

This study focuses on enhacing these operations by employing a computer based support system to assist the personnel involved in the incident management process. The goal is to support the personnel and agencies in finding approporiate strategies to mange incidents

and in the execution of the steps required to implement them. To this end the research objectives identified are as follows:

- Propose and design an Expert-GIS software architecture for incident management.
- Develop a prototype system that implements the architecture and fully integrates the software environments of the Expert-System (Nexpert-Object) and the GIS (Arc/Info). Also, as a part of this task design a develop a comprehensive street network database for a particular study area (Fairfax County in Northern Virginia).
- Design and develop a unified user interface for the prototype system from which the decision support modules can be accessed.
- Verify the accuracy and consistency of the data and evaluate the working of the system with the aim of eventual deployment at field test sites.

1.4 ORGANIZATION OF REPORT

This chapter briefly discusses the problems plaguing the incident management process and the solution approach adopted in this research effort. It also outlines the scope and objectives of this study in solving the problem identified. The next chapter reviews relevant literature and identifies the strengths and weaknesses of existing support systems for incident management. As part of the conclusions, a brief overview of the research direction adopted is presented.

Chapter 3 presents a conceptual design to the proposed Expert-GIS system. The discussion covers important issues considered during the design process and proposes an integrated framework that employs both and expert system and a geographic information system to support incident management. In addition the software tools required for the prototype development are identified. The fourth chapter discusses the implementation details and the functional modules of the prototype system - Wide Area Incident Management Support System (WAIMSS)

Chapter 5 provides a summary of typical working scenarios with WAIMSS. In addition it examines the working of the system with respect to historical incident data and evaluates the validity and usefulness of the response suggestions. Chapter 6 discusses the conclusions and recommendations of this research effort.

2. LITERATURE REVIEW

This chapter presents a review of computer based support systems designed to aid incident management operations. The discussion covers both existing systems, and conceptual architectures proposed for such systems. As a part of the section on proposed frameworks, the blackboard model is also discussed, as a suitable problem solving model for incident management.

2.1 PROPOSED FRAMEWORKS

Most studies on incident management frameworks [3, 4] stress on the actual sequence of operations and deal with specific components of the problem like duration and delay estimation, and diversion. Issues such as the evolutionary nature of the incident management operations, the presence of multiple users and the need for cooperative decision making have often been overlooked. A few studies however, have identified this issue and propose frameworks that allow a more accurate representation of response operations after an incident. These are discussed below in greater detail.

Ritchie [5] proposes a real-time knowledge-based decision support architecture for advanced traffic management. A major component of the proposed system concentrates on providing decision support for traffic management personnel for addressing non-recurrent congestion in large or complex networks. The paper identifies the important characteristics and requirements for a real-time knowledge based decision support system. These include:

- **Truth Maintenance:** As data enters the system the validity of a number of facts may change with time. The true state of the system needs to be monitored continuously. A

change in the truth value of a fact higher in the hierarchy, affects the truth value of other events.

- **High Performance:** Very short response times are usually required in the face of rapidly changing data.
- **Asynchronous Events:** Unscheduled events should be capable of interrupting the process, according to their importance levels.
- **External and Sensor Interface:** Real-time systems need to be capable of gathering data for many thousands of variables, from sensors or via database interfaces, and provide continually updated displays to the user.
- **Uncertain or Missing Data:** The system should be capable to recognize and appropriately process such data, including those from faulty or inoperative detectors.

The proposed architecture employs a blackboard model to integrate knowledge sources at different agencies and envisions networked real-time knowledge based expert systems (KBES) running initially on separate microprocessors at each agency (Fig. 2.1). To enable interactive data input to the central KBES and permit viewing of various corridor status reports some agencies are provided with networked terminal displays. Communications between the central KBES and the agency KBESs would occur via the respective database servers using the blackboard framework. The design provides decision support to traffic management personnel through five integrated modules - incident detection, incident verification, identification and the evaluation of alternative responses and monitoring recovery.

Comfort [6] in her paper on improving organizational decision making capacity in emergency management proposes a similar framework for an interactive emergency information system. Although this study does not explicitly deal with incident management operations, it is included in this discussion since it addresses many of the issues related to traffic management after incidents. The proposed architecture again employs a blackboard model to permit separate knowledge sources to interact with the global database as the time period of the emergency progresses. The design for the system concentrates on integrating

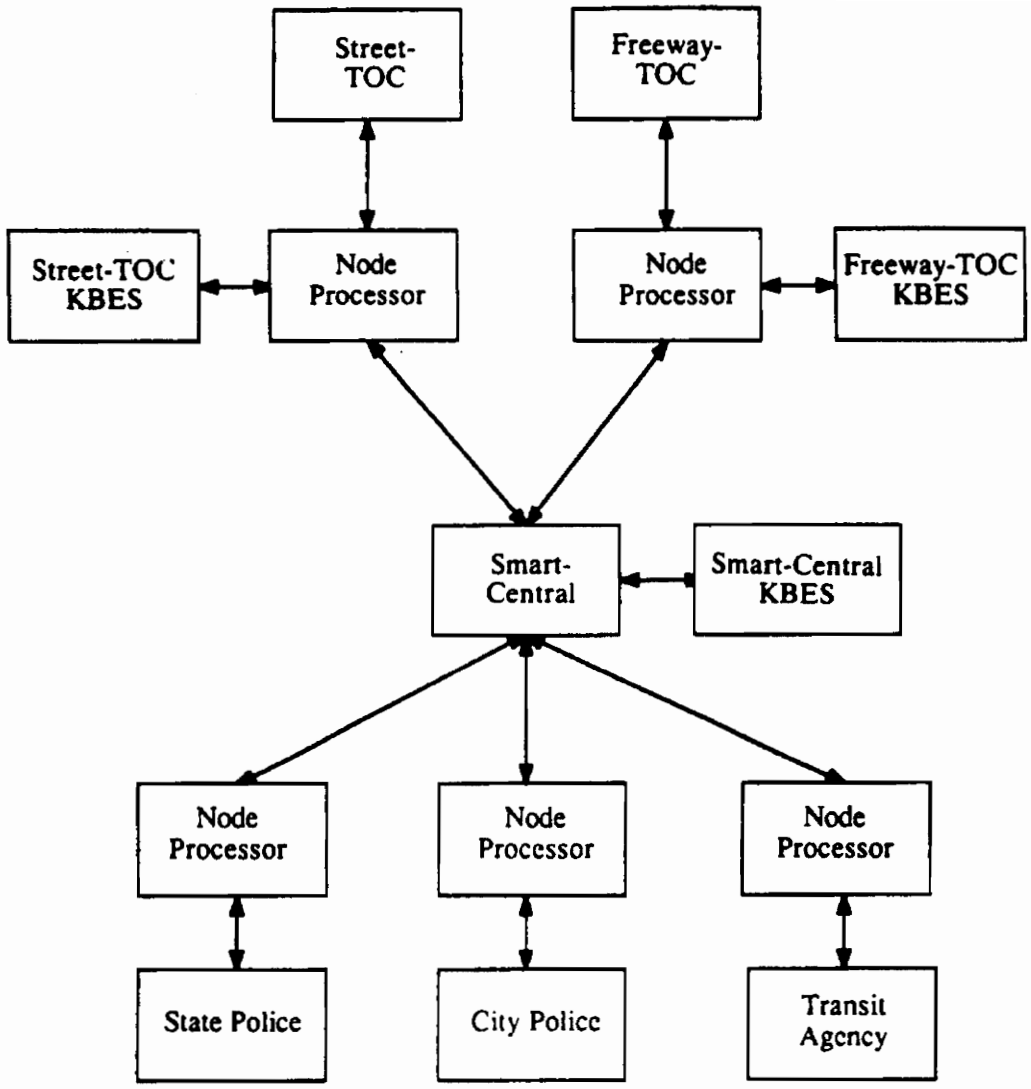

Fig. 2.1 Ritchie's Architecture for a Decision Support System
(Source: Ritchie S. G., A Knowledge Based Decision Support Architecture for Advanced Traffic Management, Transportation Research, Vol. 24A, No. 1, January 1990.)

the three issues in artificial intelligence technology - knowledge acquisition, knowledge representation and knowledge utilization.

- **Knowledge Acquisition:** This step in design pertains to the collection and organization of information to stored in the knowledge base. The paper points out that, since multiple users are involved, with complementary emergency responsibilities at multiple locations, it is essential that the knowledge be compiled in a clear, uniform terminology and in a format understandable to all users.
- **Knowledge Representation:** Efficient representation of knowledge in the design of the emergency management system is identified as critical issue from both the perspective of the users and in the design of data structures and software constructs that will be used to model the problem. The paper provides an initial schema for the organizing the knowledge requisite to an emergency information system for a city jurisdiction (Fig. 2.2). It assumes a blackboard architecture which permits different knowledge sources to interact with a global database during the response process. The knowledge to be stored in the computer is organized in separate units corresponding to the organizations which have assigned responsibilities under the jurisdictions emergency plan. The blackboard serves as a platform for interaction between the various organizations as they request information, enter new information or initiate new search strategies for problem solutions.
- **Knowledge Utilization:** This task involves the definition of the inference processes used to activate the information system. The paper emphasizes the need for the decentralizing the inferencing mechanisms in order to improve the accuracy and effectiveness of the decisions taken.

Both the architectures discussed above highlight the advantages of using a blackboard model for organizing knowledge and providing a strategy for applying that knowledge during emergency/incident response operations. The section below further reviews the blackboard model, in terms of its potential as problem solving model for incident management.

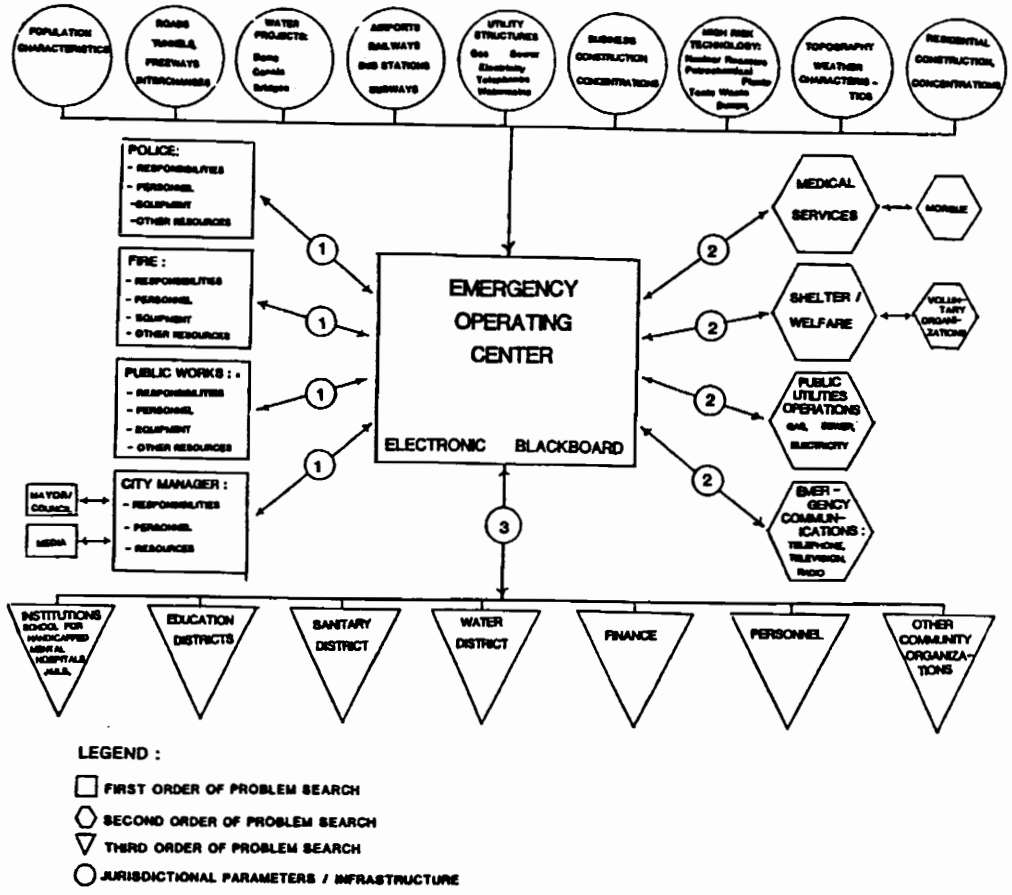

Fig. 2.2 Comfort's Architecture for an Emergency Information System

Source: Comfort L. K., "Improving Organizational Decision Making Capacity in Emergency Management: A Design for an Interactive Emergency Information System, Terminal Disasters, Computer Applications in Emergency Management, edited by Marston S. A., 1986.)

2.1.1 THE BLACKBOARD MODEL

The blackboard model was first implemented as the basis for the HEARSAY-II speech understanding system [7]. Developed between 1971 and 1976, the HEARSAY-II system responded to spoken queries about computer science abstracts in a database. Soon the blackboard architecture evolved into a robust model of problem solving and it's ability to handle complex and ill-structured problems led to development of a number of other applications. Nii [9] identifies the characteristics in a problem that make it an appropriate candidate for the blackboard approach:

- a large solution space
- a variety of input data and a need to integrate diverse information
- the need for many independent or semi-independent pieces of knowledge to cooperate in forming a solution
- the need to use multiple reasoning methods
- the need for multiple lines of reasoning
- the need for an evolutionary solution

Response operations after incidents typically reflect most of these characteristics. The blackboard model, as it's name suggests, basically tries to emulate a group of problem solvers (experts) gathered around a blackboard, solving a problem. The blackboard in this case corresponds to a shared memory that facilitates communication and cooperation among the group members. The group members are experts or sources of knowledge that contribute to the incremental development of a solution. The purpose of the blackboard is hold computational and solution state data needed for and produced by the knowledge sources. Essential components of the blackboard are as follows (Fig. 2.3):

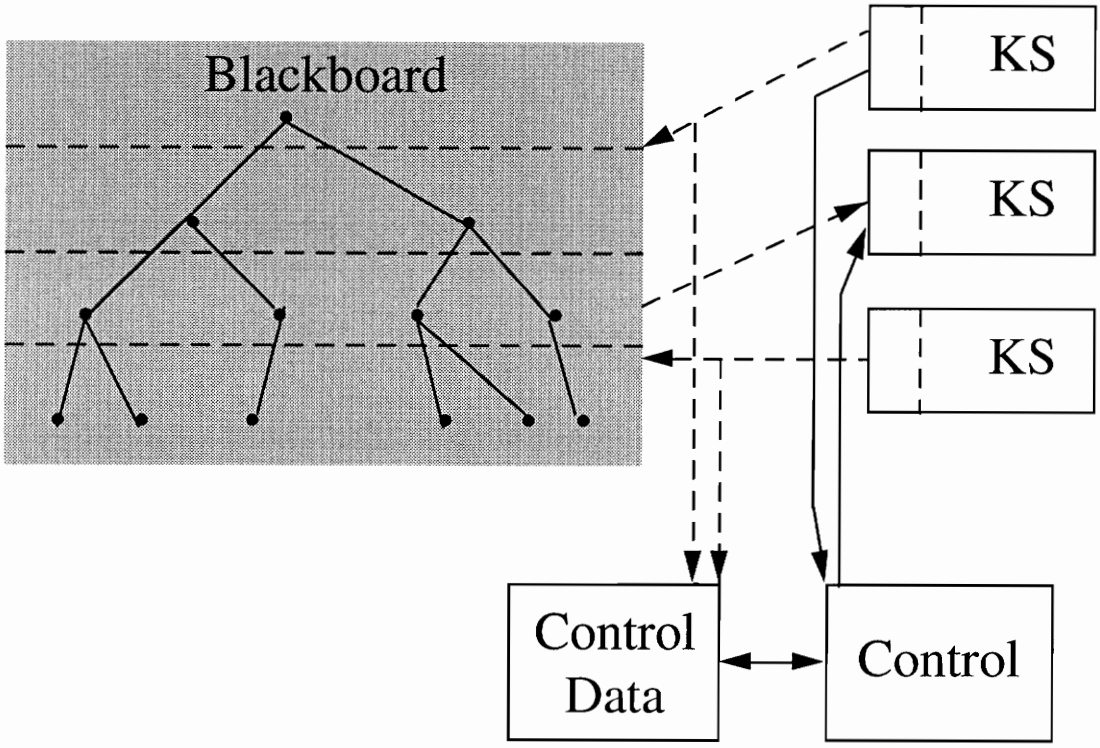

Fig 2.3 Structure of a Blackboard Model
(Source: Nii, H. P. (1986 - I), Blackboard Systems - The Blackboard Model of Problem Solving and the Evolution of Blackboard Architectures, The AI Magazine, Summer 1986)

- **The Knowledge Sources:** The knowledge sources are logically independent units that together provide the knowledge needed to solve the problem.
- **The Blackboard Data Structure:** The blackboard data structure is a global database that stores the computational and solution state data. The knowledge sources produces changes to the blackboard that lead incrementally to a solution to the problem. The blackboard serves as a common source of current information on the problem and as a medium of communication and interaction between the knowledge sources.
- **Control:** The control component provides a scheduling function to determine which knowledge source to activate given the current state of the solution. The idea behind the control component is to enable the knowledge sources to respond opportunistically to changes in the blackboard

The data on the blackboard are hierarchically organized. The knowledge sources are logically independent self selecting modules. Only the knowledge sources are allowed to make changes to the blackboard. Based on the latest changes to the information on the blackboard, a control module selects and executes the next knowledge source.

It is important to note, at this point, that the blackboard approach does not specify a specific method of knowledge representation and reasoning strategy. As Nii [8] points out, the blackboard model does not specify the realization of a computational entity and is rather a conceptual entity that provides guidelines for sketching a solution to a problem. Hence the design of a blackboard system is greatly influenced by the nature of the application problem itself.

2.2 EXISTING SUPPORT SYSTEMS

A number of computer based support systems have been built to address specific aspects of the incident management process. Of these, some approaches employ expert systems to provide decision support to operators through appropriate procedural and rule-based reasoning techniques. Another approach has been the use of Geographic Information Systems (GIS) to provide adequate information support to operators through tools to selectively query and analyze network related information. Both these approaches are discussed in the sections below.

2.2.1 EXPERT SYSTEMS IN INCIDENT MANAGEMENT

Expert systems play an important role in situations where decision makers have to deal with cognitive overloads due to ill-structured problems, dynamic conditions and/or multiple operations. In the context of traffic management and incident management an expert system can present operators with high level analyses and recommendations concerning incident response. This reduces the operator involvement needed to focus on true operational problems. It also provides for optimal and consistent traffic management

strategies, emergency response plans and travel advisories. As a result, motorist delay and other costs associated with incidents can be reduced.

Krishnaswamy [10] discusses the development of a an expert system for the selection and diversion of routes during incident conditions. Built on Kappa-PC the main aim of the expert system is to generate a set of alternate routes to divert traffic upstream of the incident. It first uses characteristics like congestion levels, available capacities and safety factors (icy bridges, height restrictions etc.) to eliminate links and arrive at a reduced network from which the alternate routes are generated. A user-equilibrium assignment module to predict traffic flows in the future is also incorporated into the framework. In addition a module which calculates the clearance time for the incident based on its characteristics is also included. Although the system was not tested over a real network, the study clearly demonstrated the advantages of rule-based reasoning in representing qualitative information about the network and expert knowledge in incident management. Considering the huge data requirements for a real network, the study strongly recommends the use of a workstation environment for future development. It also suggest using the Nexpert-Object expert system shell instead of Kappa-PC.

Ritchie et. al. [11] describe a real-time decision support system for freeway incident management and control. In this paper, the vast amounts of information flowing in to the traffic control center is stated as an important reason for automation. The freeway real-time expert-system demonstration (FRED) places very high emphasis on incident detection and verification. The FRED system currently operates on a simulated freeway network in Orange county, California. For the collection of incident data, the model uses inductive loop detectors, CCTV's, Changeable Message Signs, and ramp meters. FRED has the capability to handle multiple incidents and prioritizes the various incidents based on their characteristics (hazardous material or accident or stalled vehicle etc.). If this is not enough it studies the delay causing potential of the incidents to prioritize them. Having determined their importance, FRED makes the following decisions:

- Determines if a management team needs to be present at the incident site,
- Provides possible CMS responses and a static alternate route
- Suggests ramps that need to be closed based on the demands and the incident conditions

Expert systems have also been developed to assist the teams in incident management. Gupta et al. [12], propose the development of an expert system for Freeway Incident Management on the Massachusetts Turnpike. The expert system identifies the incident type and location and the material being carried by the vehicles that are involved in suggesting the response strategies. Based on the position of the incident, the program develops displays of pre-planned diversionary routes. These routes are checked for available capacities in real-time. The KBES developed for incident management here consists of the following components:

- **Incident Detection and Verification:** This requires a freeway surveillance system. In the system used here, passing motorists or police patrol are used for surveillance. Verification is once again done using police patrol.
- **Classification of the Incident:** Information is then provided by the police patrol on the incident characteristics, such as time, location and the severity of the incident.
- **Notification of the Incident:** This consists of notifying all the agencies required to clear and manage the incident site, after the verification of the incident.
- **Diversion Module:** This module determines if diversion is necessary and checks if the pre-planned diversion routes are available for diversion (i.e. if the volume to capacity ratio along this alternate route is less than 0.6)

The also paper explains the basic system needed for incident management. However, the different incident types considered are not complete. Also, the routes for diversion cannot be selected anew if the pre-planned routes are congested due to some extraneous factors like construction etc.

Ketselidou [13] proposes the use of an expert system model for post incident traffic control. The model in itself uses predetermined weights assigned to links based on the time of the day and the historical traffic volumes. Points at which diversion can be initiated and the potential destinations for particular links are also determined beforehand. A search process is then utilized to carry out an exhaustive search and come up with a set of alternate routes based on a set of criteria. The main modules in the model include:

- **Data Inputs:** Incident characteristics and traffic flow characteristics are obtained as major inputs.
- **Capacity Reduction Module:** This estimates the reduction in capacity of the incident link, based on the incident duration and the number of lanes blocked and decides if diversion is necessary.
- **Search Algorithm:** The search algorithm selects the best route based on the preset link weights , and assigns a portion of the volume on to that route. As a result the selection of the best route is a time consuming process and is repeated till the entire volume is diverted.

The system developed was tested on a part of the network in Long Island New York. The test network was a freeway corridor with great potential for alternate routes assessment, since there are a number of freeways and associated arterials, running parallel to each other. The results obtained were compared with those from a simulation package called TRAFLO, developed by FHWA, and were found to be fairly consistent.

2.3.3 GIS BASED SYSTEMS

The application of Geographical Information Systems to transportation problems has been drawing a considerable amount of attention over the past few years. Geographical Information Systems (GISs) are basically computer based systems for storing and manipulating geographic information. Deuker et. al. [14] provide a broader definition and refer to GISs as complex combinations of hardware, software, data, organizations and

institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth. The main advantages in using a GIS for spatially referenced information are in the volumes of data it can handle, the visual interface provided and in the speed with which the data can be accessed, manipulated, analyzed and displayed.

A GIS offers a number of advantages that make them very suitable for transportation applications. Stokes et. al. [15] note that GISs, by virtue of their ability to conduct spatial analyses, are ideally suited for many of the transportation management systems being conceived as a part of Intelligent Transportation System (ITS) programs. These programs impose new demands for collecting and integrating large amounts of information that can be referenced geographically. A GIS allows the user to integrate a variety of transportation data such as, accidents, pavement conditions, sign inventories etc. and relates this data to a particular point or road segment in a spatial referencing system. Insignares et. al. [16] discuss the advantages of applying GIS technology in Traffic Control Systems (TCS) and emphasize the fact that GISs provide a way to integrate the various advanced technologies being applied to traffic control. Using GIS techniques in traffic control systems provides an integrating force that acts to streamline the presentation of TCS information and provide a more effective means for TCS personnel to :

- collect and categorize information provided by the TCS
- interpret and analyze the information
- more quickly formulate solutions to problems that arise
- integrate geographically based TCS data from other agencies for the purpose of inter-agency analysis.

The paper further highlights the importance of geo-graphical user interfaces (G2UI) that can be provided through the use GIS and how data accumulated by monitoring devices, can be assimilated geographically for later spatial correlation or merger with other geographic data for analysis. It also points out that future GISs in transportation will tend to move away

from the role of analyzing historical data only, and will play a greater role in the analysis of real-time and historical data to serve a more predictive role.

Clearly, the ability of a GIS to manage spatially referenced information offers an advantage for transportation response operations where current information on network conditions is vital for decision making. Siegfried et. al. [17] exploit many of these advantages by employing GIS technology to improve incident management operations in a recently completed Houston project. The study evaluates the use of a GIS to relate incident locations with the transportation network and to make decisions and calculations for incident management. The system developed provides computerized mapping and database management. By using a GIS development platform it was possible to develop interrelated maps, databases, and incident management applications. This platform also provided the ability to integrate other software, for data sharing and execution, through a common user-friendly interface (Fig 2.4).

The prototype applications developed for the automated incident management plan are classified into two groups. The first type pertains to incident management operations; the second type pertains to planing and analysis for incident management. The user-friendly interfaces developed for the applications can access historical or real-time traffic data to provide input for management decisions. In addition, the applications developed were integrated with PASSER-II, for intersection operational data updates, and CAMEO, for independent execution, to perform area wide chemical emergency management. The applications for incident management operations include the following:

- **Alternate Routing:** Depending on the need, alternative routing can be performed over -(i) a local area, using frontage roads for incident affected freeways; (ii) a wide area, using corridor arterials; (iii) a hazard area.
- **Incident Response:** Incident response plans can be provided for - (i) blocking of individual freeway lanes for the purpose of alternative routing; (ii) automated blocking of

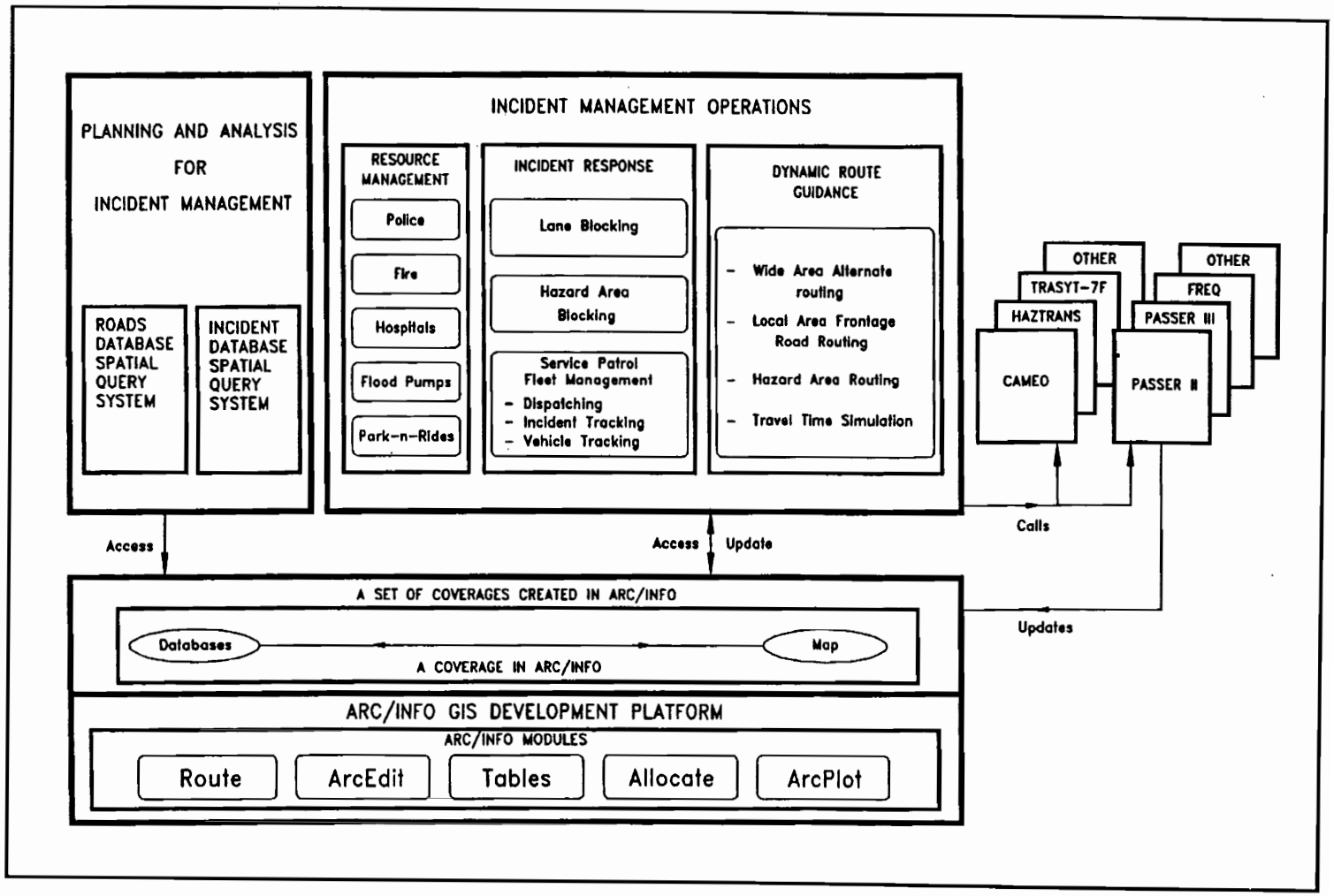

Fig 2.4 System Architecture of the Automated Incident Management Plan
(Source: Siegfried, R. H., Vaidya N., Automated Incident Management Plan Using Geographic Information Systems Technology for Traffic Management Centers, Research Report 1928-1F, TTI, Texas A&M University, July 1993)

a hazard area; (iii) automated tracking of incidents and dispatching one or more of available vehicles from incident response fleet.

- **Resource Management:** Resources required for incident management operations include police and fire station, hospital, and critical flood pump location. These resources could be managed by - (i) providing spatial queries to obtain names, addresses and phone numbers of organizations/individuals to contact when required; (ii) providing spatial queries on the features, capacities and availability of the sources.

Applications for planning and analysis for incident management were also provided to analyze roads and incidents, separately or in conjunction and devise plans for improving traffic flow. These include:

- **Road Database Query:** The road database query system permits spatial queries on the roadway inventory database as well as graphical results of queries on the database. Queries can be performed on a variety of attributes in the roadway inventory.
- **Incident Database Query:** The incident database query system provides the ability to perform spatial queries on the number and types of incidents on any section of freeway. Response to some queries could be shown graphically.

The prototype applications were developed using PC-Arc/Info on a PC/486 microcomputer. Arc/Info modules were used for the development and operation of these applications. Data Conversion and Overlay modules were required for development. The development process identifies available map databases and other issues that must be addressed prior to implementing a large scale automated incident management plan. Most of the functions were automated using PC-Arc/Info's Simple Macro Language (SML). The SML programs, operate within the Route module and call other modules whenever needed.

An important finding of this study is that a PC platform may not suitable for real-time traffic management systems, such as automatic vehicle identification based on traffic monitoring, where new data is received at short intervals of few seconds. In addition, PC-Arc/Info is

slow when compared with other commercially available relational databases and SML is rather limited in scope and function. The study strongly recommends the use of a workstation environment and the use of a programming language that parallels a higher level programming language.

2.4 CONCLUSIONS

The architectures proposed by Ritchie and Comfort are a significant contribution since they recognize the need to support both strategy development and the various individual and agency level interactions that take place during incident management. Issues related to multiple users and the need for coordinated decision making have often been neglected, and still plague many of the incident management operations. In this aspect the blackboard model provides a very suitable framework for a more accurate representation of the problem. It provides a platform for information sharing and exchange between different working groups and allows for an incremental and cooperative development of a response strategy with input from many independent or semi-independent (agencies, telephone calls, etc.) sources of knowledge.

An important drawback, however, of the above architectures is the fact that they do not adequately address the spatial nature of the incident management process. The process in itself involves collecting and integrating large amounts of geographically referenced information (network information, agency locations, resources, etc.) the frameworks are limited by their failure to design for the spatial component of the problem. Existing expert systems in incident management also overlook this aspect. In addition, most of these systems deal with one specific component of incident management and do not address the need for coordinated decision making. For e.g. the Freeway Real-Time Expert System Demonstration (FRED) focuses on incident detection and verification and does not provide adequate support for response plan generation diversion planning.

The system developed by Siegfried et al. recognizes the spatial aspect of incident management by employing a geographic information system. With a GIS as the development platform, the prototype application developed aids decision making by providing facilities for querying and manipulating large volumes of geographically referenced data. However, the application lacks tools for high level analysis of this data using procedural and rule based reasoning. The overall architecture also fails to recognize the need for coordinated decision making and information sharing between the agencies involved in the incident management process.

In summary, existing systems address some specific aspects of the incident management process, but fail to comprehensively support all components of the problem. Given the fact that the entire process is a cooperative effort, there is a need for support systems that address both the substance of the task/problem/decision and the various individual and agency level interactions that take place during the response process. The system proposed as a part of this study attempts to overcome these drawbacks through the design of a Group Decision Support System that employs both an expert system and a geographic information system. The approach and the methodology adopted in the development of such a system is described in the chapters that follow.

3. DESIGN CONCEPTS & METHODOLOGY

This chapter presents a conceptual design for the proposed Expert-GIS system. The design strives to eliminate the drawbacks identified as a part of the literature review. The discussion covers important issues considered during the design process and proposes an integrated framework that employs both an expert system and a geographic information system to support incident management. In addition the software tools required for the implementation of such a framework are identified.

3.1 DESIGN CONSIDERATIONS

The main focus in the design of a conceptual framework for a support system is to accurately represent the nature of the process and appropriately address the issues requiring support. In addition, the real-time nature of the required support means that the system must satisfy demands that do not exist in conventional domains where inputs are static and time critical responses are not required. In the above context, it is necessary to consider the following issues:

- providing a database management system to support the storage and retrieval of static and dynamic information pertaining to the incident and the road network.
- ability to incorporate the knowledge of experts in the field and apply this knowledge to provide decision makers with high level analysis and recommendations.
- utilities to selectively query, analyze and manipulate information in response to the situation.
- a high level of visualization capabilities that can be used to present large amounts of information in a cohesive and context related manner.

- coordinating the efforts of the multiple agencies involved in each operation.
- providing a platform for communication - information exchange and sharing, between the different working groups.

Basically the design should serve as a vehicle for organizing relevant knowledge for decision making, in a format that is readily accessed by multiple decision makers at multiple locations. Accomplishing this task will facilitate a secondary function essential to effective incident management, the cooperation and coordination of actions within and between multiple organizations with complementary incident management responsibilities.

3.2 OVERALL CONCEPT

The overall objective of the proposed design is to assist various incident management personnel involved in finding the appropriate strategies to manage incidents, and support execution of steps required for their implementation. Since these strategies usually call for a cooperative effort by several agencies, the architecture not only concentrates on addressing strategy development but also on supporting the various individual and agency level interactions that take place. Hence it incorporates the two important facets of incident management:

- **Problem Content Support:** Content support may be described as the extent to which the computer based-system (hardware, software application programs, algorithms, heuristics, etc.) is capable of providing support to its users (individual or a group) in addressing issues related to incident management. These include incident duration estimation, delay prediction, clearance strategies, diversion strategies etc.
- **Group Process Support:** This functionality facilitates and improves the dynamic group decision process by enhancing participation and information exchange among the different groups working to manage each incident.

Support systems designed to serve both these functions are often called Group Decision Support Systems (GDSS) or simply Group Support Systems (GSS) [18]. A GDSS is an interactive computer based system which facilitates solution of unstructured problems by a set of decision makers working together as a group. Components of a GDSS include hardware, software, people and procedures. The decision support architecture discussed in the following sections, is founded on this concept of a GDSS. It makes an important distinction from conventional support tools, by including the people involved as an integral part of the design. Thus it incorporates the interactions that take place during problem solving.

In order to provide the required decision support and information management capabilities, the architecture proposes an application that combines powerful spatial data handling capabilities of a Geographic Information System (GIS) with the rule based logic of an expert system. These applications will support operations at each of the participating agencies. A blackboard framework is then employed to integrate the individual applications at various agencies and provide the required group process support. The following sections discuss the above concept in greater detail in terms of its individual components - a framework for integration, the application design and the decision support modules.

3.3 FRAMEWORK FOR INTEGRATION

The framework for the proposed system employs a blackboard architecture, to support incident management operations by providing facilities for spatial and temporal data analysis and a mechanism for interaction between different responding agencies. Figure 3.1 shows the overall decision-support blackboard model. For simplicity, only four agencies are shown - the traffic management center, the department of transportation, state police and a local agency. However, the idea represented can be used to integrate all the agencies involved in the incident management process through the blackboard.

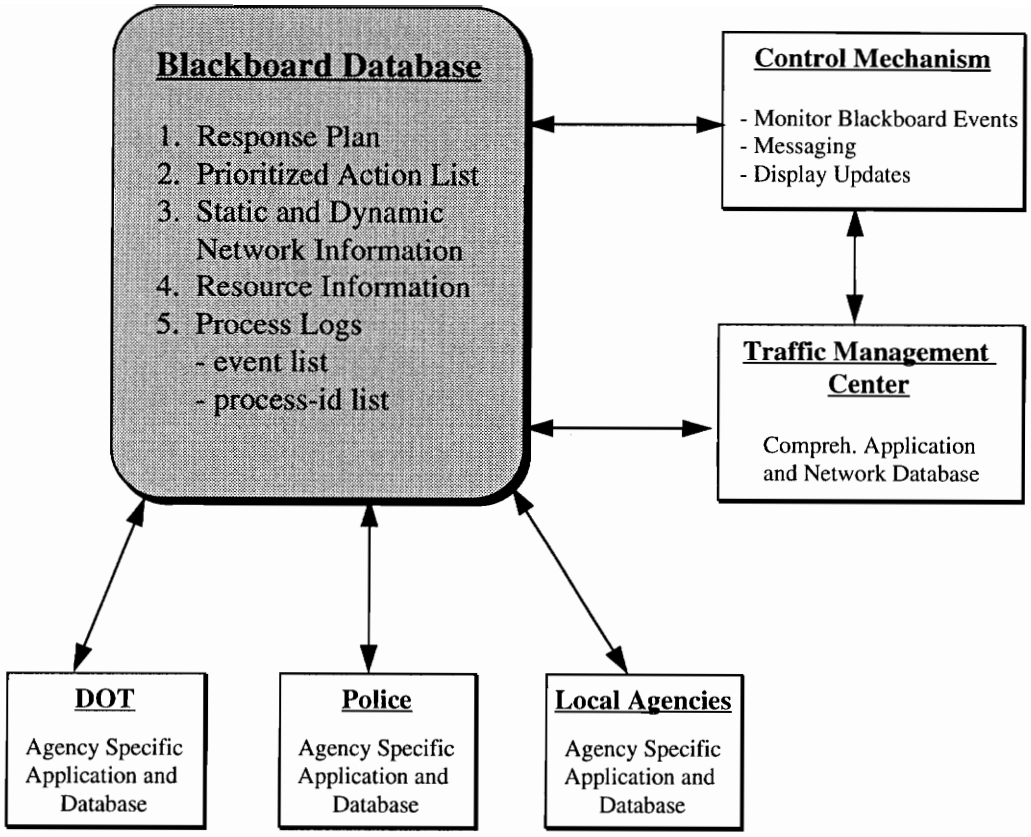

Figure 3.1 Conceptual Blackboard Framework for the Group Support System.

The blackboard corresponds to shared memory that is assumed to be located at the server in the traffic management (TMC) center. Each agency is equipped with applications that facilitate communication with the blackboard. Information that needs to be shared during the incident management process is recorded on the blackboard. The blackboard also serves as the global database for the system and helps in recording, searching and identifying possible strategies for response to an incident. It monitors the status of the actions taken and records the tasks that have been addressed or solved. Further, it helps in messaging between agencies and updating displays when required.

The blackboard is organized into five distinct areas (Figure 3.1). The first is the response plan which represents the current set of strategies chosen to manage the incident. The decisions taken for the allocation of resources, personnel and equipment is recorded with

provision for updating the status of these events as new information is reported. Once all the posted strategies are agreed upon, the plan takes final shape and is considered ready for implementation. The second area of the blackboard fixes the agenda for action and reports tasks in their order of priority. The third and fourth components of the blackboard store relevant information about the network and the available resources. This information may be static information like network geometry, lane capacities and link lengths or dynamic information like current link volumes, weather conditions and available resources like wreckers, ambulances etc. Finally, the blackboard maintains a continuos log of events after a particular incident. The log also includes a list of process-ID's of the different agency applications connected to the blackboard. These ID's are used by individual agencies to share and exchange information on current incident conditions and response alternatives.

3.3.1 APPLICATION DESIGN

The agencies involved in the incident management process (Figure 3.1) are equipped with site specific support tools and databases. These tools allow for connecting to the blackboard and utilizing the current incident information for response operations. In addition, each of these applications is used to provide information and decision support for functions addressed by that agency. In order to serve these two functions, each application is built as a combination of an expert system and a geographic information system.

The expert system uses rule based reasoning to provide decision support for operations like duration estimation and alternate routing while the GIS provides data and information management capabilities and provides an interface for spatial analysis and manipulation of network information. Figure 3.2 provides a schematic of how the two systems will work together. Under this architecture, the expert system uses the network and incident information stored in the GIS database to provide the operator with high level analyses and response alternatives. The operator is free to accept or reject the proposed course of action, or even study other alternatives by changing the analysis parameters and data. The GIS is also used to synthesize different data sets (road network, historical incident data, diversion

routes, etc.) to create new information based on the properties of the elements in the database. In effect, their combined interface delivers tools to access information in the GIS database in a context related manner and further process this information using the combined knowledge of experts in the field.

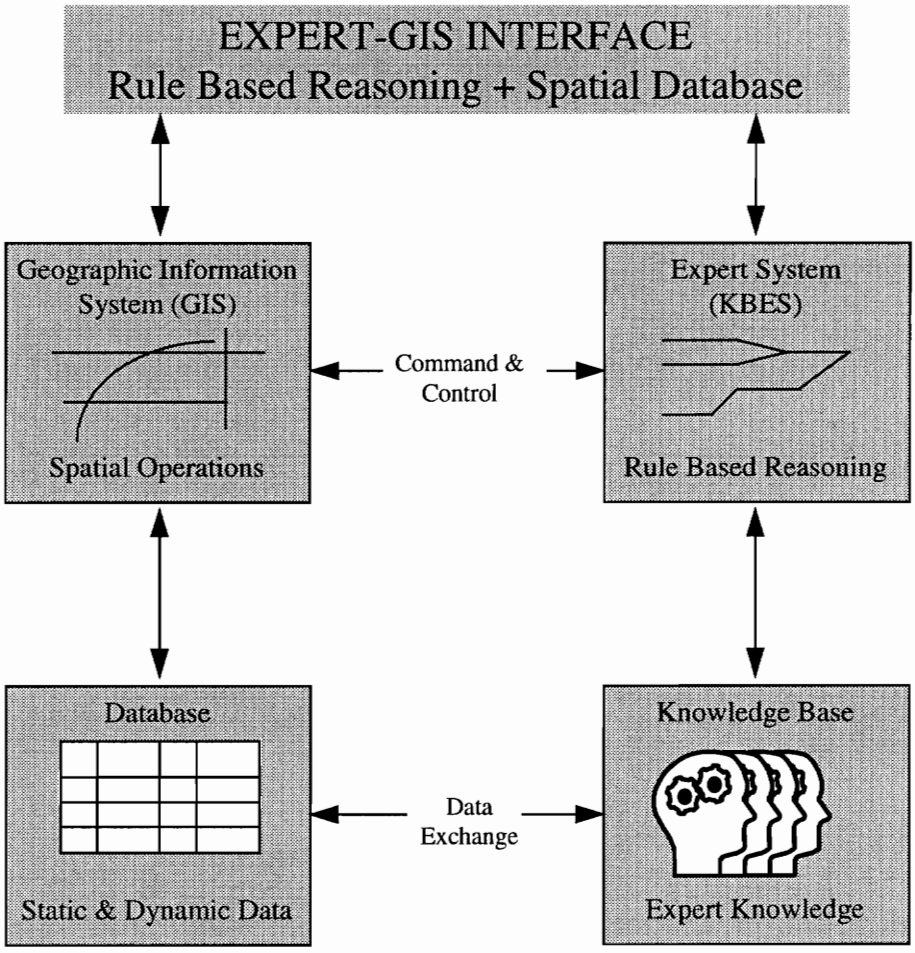

Figure 3.2 Expert-GIS Architecture for the Applications.

For the support system under consideration, a GIS database at a particular agency will be used to store information regarding their personnel, equipment and other resources. The expert system will provide the knowledge base and heuristic reasoning capabilities for the functions addressed by that agency. The traffic management center on the other hand is

equipped with a comprehensive support system dealing with all aspects of incident management and a complete road network database since most of the decisions regarding the response actions will be taken at the TMC. In addition, the TMC application, acts as a control mechanism and monitors changes on the blackboard and decides on the plan of action.

3.4 DECISION SUPPORT MODULES

Decision support for traffic management operations after an incident is provided through a six integrated modules (Figure 3.3). These include incident detection and verification, duration estimation, delay calculation, response plan generation and recovery.

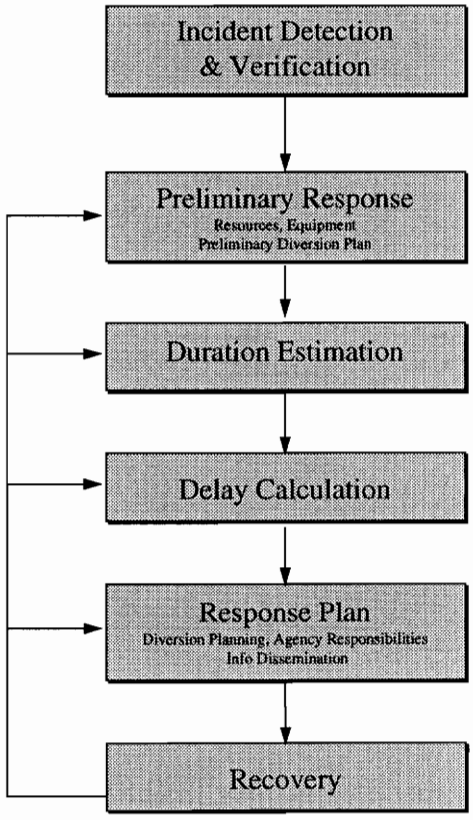

Figure 3.3 Decision Support Modules.

The application at the traffic management center deals will all the above aspects while the individual agency applications deal with one or more subsets. Based on its responsibilities and areas of expertise, each agency contributes to managing an incident while the traffic management center oversees the whole operation and coordinates individual agency efforts. The sections below discuss each of these support modules in greater detail.

3.4.1 INCIDENT DETECTION AND VERIFICATION

The incident detection and verification module will take in operator input about the incident characteristics and request verification from the traffic management center based on incoming motorist calls from cellular telephones and/or verification by on-site personnel. In due course the module will complement existing and on-going research on incident detection algorithms for surface streets and freeways. The algorithms developed can be integrated with appropriate closed circuit TV cameras whose locations will be stored as a part of the GIS database. This functionality would allow automatic selection and activation of the appropriate camera for operator viewing and, obtaining and accessing additional information for incident verification.

3.4.2 PRELIMINARY RESPONSE

Establishing a preliminary response is one of the first steps in the case of any incident. The preliminary response module provides an initial estimate of the resources need to clear the incident and judge if diversion is necessary. In most cases this estimate will have to be provided with incomplete information about the incident and the traffic conditions. The expert system at the traffic management center will have to use historical incident information and the available current information to suggest a preliminary set of guidelines for managing the incident. These guidelines are then communicated to the required agencies through the blackboard. Table 3.1 shows some of the response variables evaluated by this module and the agencies involved.

Table 3.1 Preliminary Response Module

Suggestion/Response	Agency Advised
Incident Alert	All Agencies
No. of Police Vehicles to Use	Local Police/Virginia State Police
No. of Wreckers	Towing Company/Police/VDOT
No. of Ambulances	Hospitals/Rescue Squads/Red Cross/Other Medical Agencies
Diversion Strategy	Police/VDOT/Virginia State Police

Based on the variables identified the responding agencies finalize their portion of the response and update the blackboard with information on the variables identified. This enables the system to predict the duration, delay and required diversion strategy with greater confidence.

3.4.3 DURATION ESTIMATION

This module attempts to estimate the duration over which the effects of the incident will last. This is basically the time involved since the verification of the incident to the moment when the roadway is cleared of all incident debris and the response crew have left the scene. This period includes the following components:

1. time for arrival of all the required equipment for the clearance,
2. time for setting up equipment and completion of clearance of all incident elements including debris from the roadway travel lanes,
3. clearance of all incident vehicles and debris from the shoulders, if any, and roadway restoration for normal traffic flow.

Several factors need to be considered by this module in estimating the duration. They include the incident type, location of occurrence, time of occurrence, resource availability, lane configurations and blockage, shoulder availability, weather conditions prevailing at the time, and spatial/locational aspects of the incident occurrence. Data on these factors will be processed by the expert system in conjunction with information from a historical database of

incidents to arrive a reasonable estimate for the current incident. The duration predicted by this module carries special significance for incident management, and could be used to determine a number of response actions.

3.4.4 DELAY CALCULATION

The role of this module is to aid decision makers in making a reasonable estimate of the network wide delays due to an incident. In calculating the network wide delay, the following factors have to be modeled:

1. Incident type, location and lane blockage
2. Incident duration
3. Time of occurrence - demand at incident location
4. Incident clearance process and the traffic management plans employed

Of these factors, the incident duration is obtained from the preceding duration prediction module, while the other parameters such as location, type, existing and current capacities, traffic volumes (demand), etc., can be extracted from the GIS database. An important factor to be considered in the design of this module is the variation in traffic demand due to the extent of incident information available to motorists upstream of the incident location. Although at this stage, it is not possible to collect real-time traffic volumes provisions should be made to readily integrate sensors on freeway with the GIS system. This will automate the data collection process and provide accurate real-time estimates of the traffic flow after an incident.

3.4.5 RESPONSE PLAN

This module attempts to identify and evaluate response strategies to an incident. In doing so it will not only require the identification of feasible responses, but also on-line traffic and network forecasting and modeling for evaluation and refinement of alternatives. Initially,

pre-planned and pre-agreed responses and actions could be jointly developed by the operating agencies, prior to development of an on-line capability. Current incident response methods in existing traffic management systems are often complex and involve considerable operator judgment as well as familiarity with extensive procedures outlined in the in-accessible and little read reports and manuals. At the initial stage of development this module will organize this information and make it easier to use through relevant suggestions and tools to easily access and view the available options. The list below outlines a possible set of responses that will be modeled:

- selecting and implementing diversion strategies - both historical routing plans and dynamically generated alternate routes will have to be evaluated
- modifying surface street signal timing plans and initiating ramp metering changes
- activating and dispatching freeway incident management teams - these would include maintenance crews, traffic control officers and rescue squads
- dispatching tow trucks and emergency services on both the freeway and surface street system
- locating and activating mobile and ground mounted changeable message signs at access ramps and other upstream sections of the freeway
- coordinating with other agencies and the media
- issuing and updating real-time traffic reports and recommendations through motorist information systems - as information services like highway advisory radio, in-vehicle navigation systems and traffic information displays are implemented, this process can be automated and the GIS component of system can be used to remotely monitor these facilities.

In effect, this module will support the implementation of selected responses and help in determining consistent courses of action by all relevant agencies. The blackboard in conjunction with the application at the traffic management center would then support communicating these action plans between agencies and monitor confirmation of their implementation.

3.4.6 RECOVERY

This module aids in monitoring the implemented response strategies and in assessing the effectiveness of the measures taken. It will present the results of these assessments through graphical displays and assist the operator to determine if further responses are required. In a sense, this module will provide the required feedback to the preceding modules in order to refine implemented plans based on the conditions at the incident site.

3.5 SOFTWARE TOOLS

The software tools available for the development of the Expert-GIS system were carefully reviewed and evaluated. The workstation (UNIX) version of ARC/INFO was chosen as the GIS platform and NEXPERT-OBJECT was picked as expert-system shell. The choice of these two software tools was based on the recommendations made by previous studies [10, 17], and the distinct advantages offered by these tools in the development of a real-time system. In addition, Neuron Data's Open Interface Elements was selected as the toolkit for building a graphical user interface for the system. The sections below, discuss briefly the capabilities and advantages of these software tools.

3.5.1 ARC/INFO

Arc/Info, developed and supported by the Environmental Systems Research Institute, Inc. (ESRI), is a powerful toolbox that supports the entire spectrum of GIS applications. Spatial objects in Arc/Info are represented as points, lines or polygons. The locational data associated with these objects are defined through a topological model, while the thematic data are defined using a relational data model in Info. The basic unit of storage in Arc/Info is called a coverage which corresponds to a single layer of a map that contains information about one type of locational feature [19].

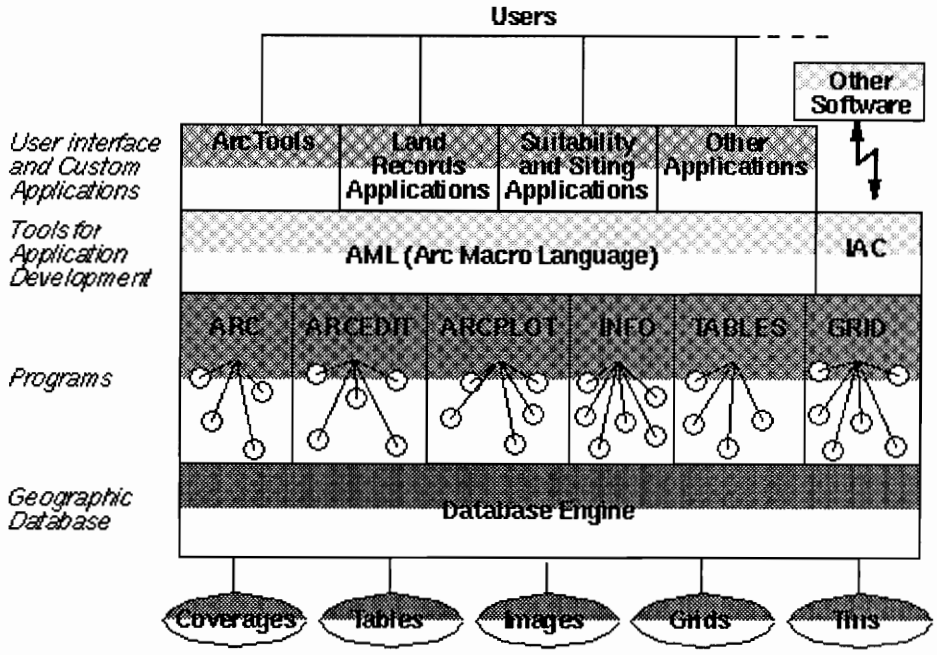

Figure 3.4 The ARC/INFO Architecture
(Source: Environmental Systems Research Institute (ESRI), Inc., Arc/Info User's Guide,. Getting Started - Introduction to Arc/Info, 1994)

Arc/Info has a layered architecture [20], the foundation of which is the data engine used to access and manage the geographic database. At the next level, Arc/Info contains a powerful and flexible command language, providing access to sophisticated geoprocessing tools which operate on the various data sources supported by Arc/Info. AML, the ARC Macro Language, provides the development environment in which sophisticated macro procedures can be automated and custom user interfaces can be built. A third method for accessing Arc/Info is through the use of inter-application communications (IAC). IAC tools in AML allow other applications software to execute operations in Arc/Info, thus allowing its use as a GIS data and process server. These capabilities of Arc/Info make it especially suitable for the design of the system described.

The decision to use the above software was also influenced by the fact that, ARC/INFO can handle a variety of data formats. This is an essential feature since transportation data is usually acquired from a number of different sources and does not always conform to an

established standard. In addition, built in functions in ARC/INFO support a number of transportation applications and allow for easy interfacing with existing transportation software. Moreover, ARC/INFO is the most widely used GIS software and caters to a number of public and private agencies. In general, ARC/INFO was found to be the most comprehensive GIS development platform that could support the development of the system as currently envisioned.

3.5.2 NEXPERT-OBJECT

Nexpert-Object, developed and supported by Neuron Data, provides a framework for the construction of rules, and an object-oriented model for representation if the data that the rules act on. A Nexpert rule consists of three parts - a series of conditions, a hypothesis, and a series of actions. If all conditions are true then a hypothesis is true, which can be used to execute a set of actions [21]. Nexpert's rules act on objects which are members of classes and possess properties. Objects and classes are incorporated into the conditions and actions of the rules. Rules can change object class memberships or the values of its properties. Together the rule and the object networks form the knowledge base of the expert system.

Nexpert-Object was chosen for the expert-system side of the Expert-GIS since its application programming interface (API) makes the task of integration relatively easier. In addition, its object oriented data model offers a great deal of flexibility in data representation, and its ability to reason by both forward and backward chaining offers a similar flexibility in logic representation. Although Nexpert has built-in data base conversion modules for several popular data-base systems, it unfortunately does not support Info, the database used by Arc/Info in the UNIX environment.

3.5.2 OPEN INTERFACE ELEMENTS

Neuron Data's Open Interface Elements was chosen to build additional graphical user interfaces that the system needs. Selecting an interface toolkit was necessary since the

interface utilities provided by both ARC/INFO AML are limited and provide a very elementary set of widgets. Open Interface is a software development environment that permits the development of cross platform applications with high-level graphical interfaces [22]. Open Interface comprises a set of libraries and a resource editor. It also has a C language API which is a highly modular ANSI C library. The API provides facilities for developing applications with graphical user interfaces for any standard windowing environment.

An important consideration when choosing to use these tools is bridging the different software environments of Arc/Info and Nexpert-Object and Open Interface to permit easy transfer of data and command level control between the software. The next chapter discusses these issues in greater detail and explains the bridging mechanism employed in the development of the prototype Expert-GIS.

4. PROTOTYPE DEVELOPMENT

In keeping with the objectives of this research effort, a prototype group decision support system for incident management was developed. This system is called the Wide-Area Incident Management Support System (WAIMSS). The previous chapter presented an overview of the design concepts and software tools employed for the development of such system. This chapter discusses the implementation details and the functional modules of the prototype system - WAIMSS.

4.1 NATURE OF DOMAIN

The road network in the Fairfax County in Northern Virginia area was chosen as the domain for building the prototype system. The freeway system in this area includes interstates like I-66, I-95, and I-495 and the Dulles Toll Road. Figure 4.1 presents a map of the of the major roadways in this area. With a population of around 700,000, this area is highly urbanized and has high rates of travel on all its roads. Recurring as well as non-recurring congestion are common events and cause delays on both the interstates and the arterials. The Traffic Control Center in Fairfax City is the central location from which this road network is managed to ensure smooth flow of traffic.

Incident management in the area is carried out by freeway incident management teams comprising of number of local and state transportation and emergency service agencies. These include agencies such as the Virginia State Police (VSP), Virginia Department of Transportation (VDOT), City and County Police, Fire and Rescue agencies and even media representatives. The Northern Virginia Freeway Management Team Operating Manual [1] is used as a guideline by personnel for responding to incidents. The manual outlines the

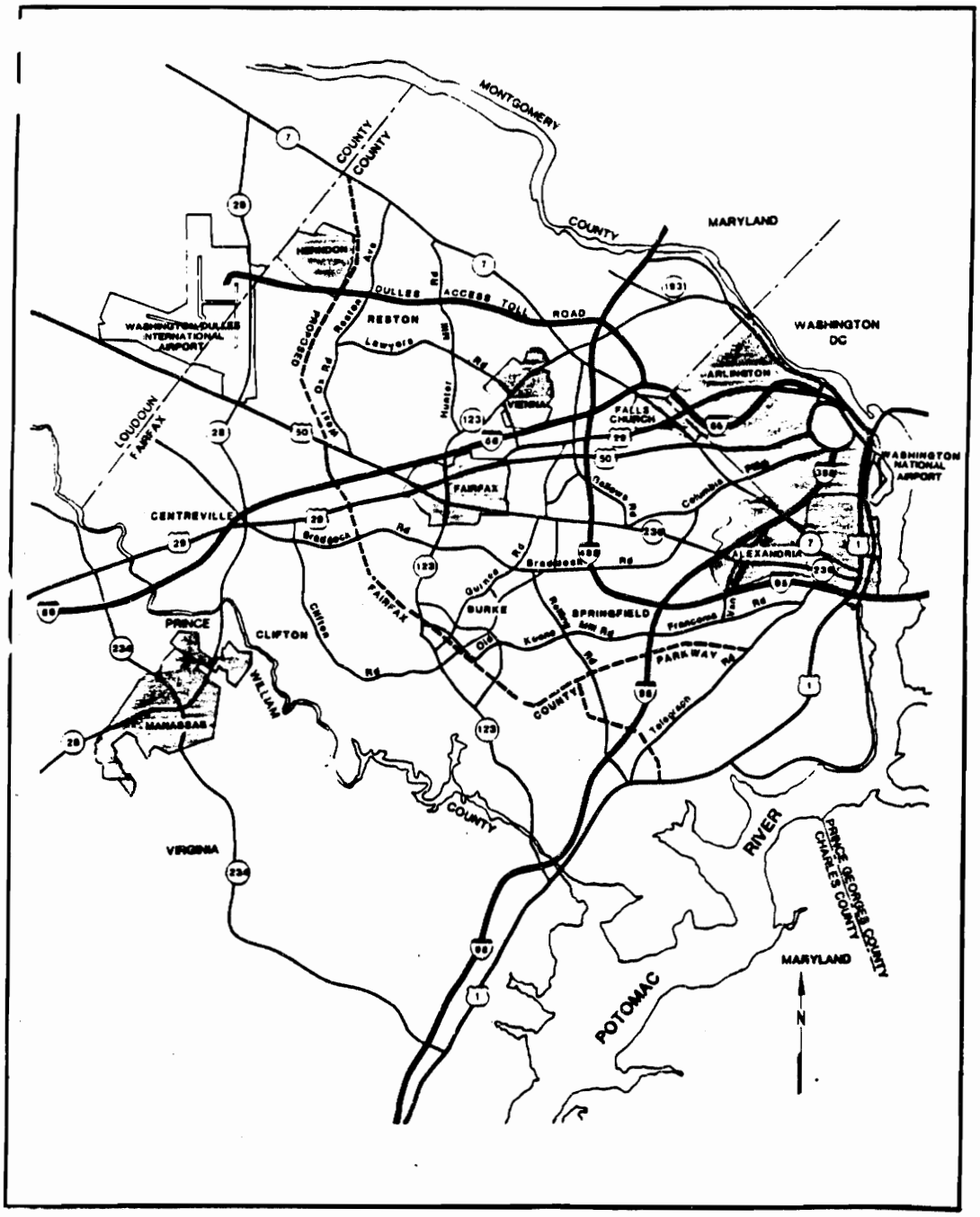

Figure 4.1 The Northern Virginia Road Network

(Source: Virginia Department of Transportation (VDOT), Northern Virginia Freeway Management Team Operating Manual - A Regional Plan for Traffic Management on Northern Virginia Freeways, April 1990)

procedures to be followed by personnel responsible for various aspects of freeway incidents. Organized into six sections it addresses the following issues:

- General information on incident management and the scope of the manual
- Interagency responsibilities and agreements
- VDOT policies and information
- Other agency information
- Emergency telephone numbers and equipment
- Alternate route plans

Basically, it provides the information required for creating the mutual understanding of the responsibilities and coordination among agencies. Other aspects of managing the incident are carried out using general rules of thumb and practices established over time. For e.g. some of the current practices followed for diversion are as follows:

- Diversion is not attempted for any incident with a duration of less than two hours. This is because it often takes more than two hours to set up the alternate route, by which time the incident has already been cleared.
- Routes for diversion are selected from a book of maps that have been prepared in anticipation of the an incident on every freeway link. Many of these maps are based only on the shortest feasible distance that ensures access back to the freeway. They do not consider the incident severity or other real-time traffic conditons such as current construction and maintenance work, school openings etc. As a result, secondary incidents on the selected alternate routes often occur and add the existing problem.

The above practices, as can be seen, leave little scope for the evaluation of possible alternatives and the use of the best available option. Given the scope of the problem and variability in the operating conditions, it has always been a problem for the incident management teams to function without further automated assistance. The prototype system

focuses on this issue and aims at providing the required support to operators and personnel in choosing appropriate response strategies and evaluating available options

4.2 SYSTEM INTEGRATION

The prototype system (WAIMSS) is presently implemented over a server-centric client-server architecture. The system uses a Sun Sparc 1000 as a central server with Pentium-PC's running an X windows emulation software at the client sites. The idea is to have the central server at the traffic management center with agency specific applications and databases developed for each client as shown in Figure 4.2 In addition, the server also supports the blackboard, and the TMC applications and databases. Client sites request data from the blackboard and view events related to the progress of the incident response on the blackboard. Communication among the different client applications and the blackboard was achieved using the inter-application communication (IAC) facilities in Arc/Info. Future plans aim to port the system to a client-centric environment so as to reduce the processing loads on the main server. Under this scenario agency applications will reside at their respective client sites.

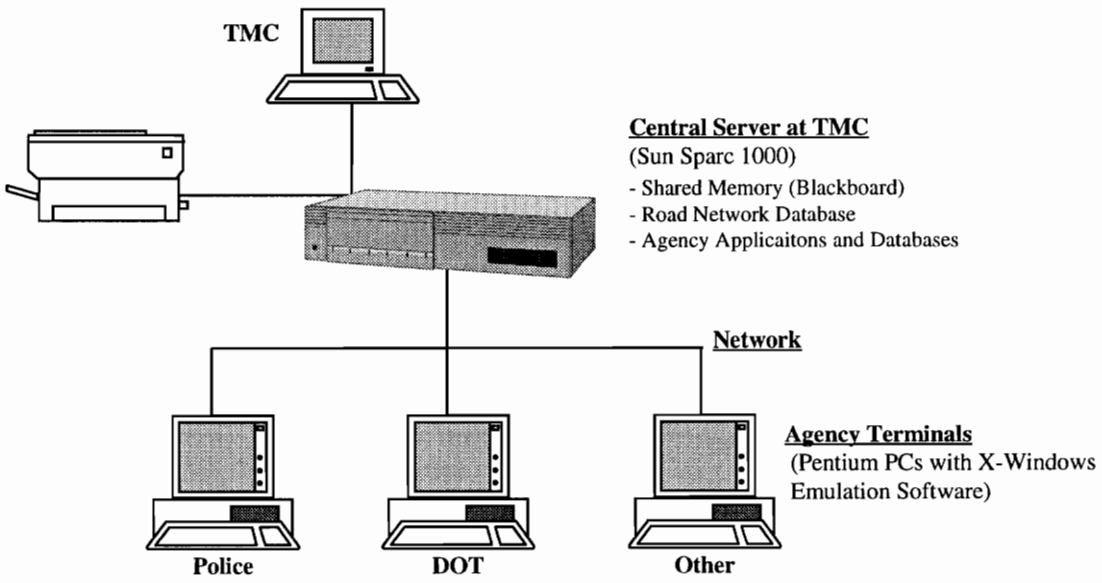

Figure 4.2 Integrated System Architecture

The control mechanism for the system was implemented as a part of the TMC application using Nexpert rules and AML macros. The Nexpert rules were used to monitor the changes in the response plan and decide on when to broadcast messages and update displays at agency terminals. The AML macros were used to define roles and the necessary read/write restrictions for the various agencies. The messaging and display updates initiated by the control mechanism required an additional input/output channel at each of the agency applications. This was made possible by starting up each agency application as an Arc/Info server session and storing details about its hostname, program number, and version number in a 'connect-file' as a part of the process-id list. This additional input/output channel was used to popup message windows and update displays from another agency application. The individual components of the blackboard, as discussed in the previous chapter (Figure 3.1), were implemented as follows:

- **Response Plan Information:** The response plan for an incident constitutes the list of agencies that are needed to respond to the incident and the resources they will need. In addition the information on diversion routes and the people who need to be contacted at each agency are made available. Presently WAIMSS stores this data in Info at the shared memory location on the server. An Open Interface front end and the Arc Map display are used to view this data from each client site through IAC client requests or automated display update through the control mechanism.
- **Prioritized Action List:** The prioritized actions list is maintained at the shared memory location as a text file. The actions in the list are created by the control mechanism based on the current deficiencies in the response plan.
- **Static and Dynamic Network Information:** Static and dynamic information on network conditions are stored as a relational database in Info. The Info files are accessed by each client application. The control mechanism is used to enforce the required read/write restrictions into this database based on the roles assigned to each agency. AML macros were used to define the roles.
- **Resource Information:** Resource information is stored as related Info files.. Resource data that needs to be shared is stored at the shared memory location. Agency specific

database may contain additional information which other agencies may not need. As in the case with static and dynamic network information read write restrictions are enforced by the control mechanism. Additional resource information is added to the existing files when necessary from the local databases by the TMC using the messaging component.

- **Process Lists:** These are maintained as text files at the TMC. The event list maintains a log of all the changes made to the central database. This is implemented using a macro that writes to the event list each time a write operation is executed on the central database. In addition, a list of the process-ids of each agency Arc/Info session is also maintained. These id's are used by the control mechanism for communicating and passing messages between the different sessions.

4.3 APPLICATION DEVELOPMENT

Individual applications in WAIMSS were developed using the Expert-GIS approach discussed in the earlier chapter. WAIMSS applications combine the rule-based reasoning capabilities of the Nexpert-Object expert system shell with the spatial data handling capabilities of Arc/Info (Figure 4.3). Linking the two development tools allowed both the expert system and the GIS to perform new tasks and opened the way for complex spatial analysis and more flexible querying of the GIS database.

Using the interface development toolkit - Open Interface, it was possible to overcome the limitations imposed by AML of Arc/Info and provide a unified and intuitive interface for the applications. A key element in the implementation for the Expert-GIS design was bridging the different software environments of Arc/Info and Nexpert-Object and Open Interface to permit easy transfer of data and command level control between the software. The two level of integration - data level and command level, that were implemented are discussed in the sections below.

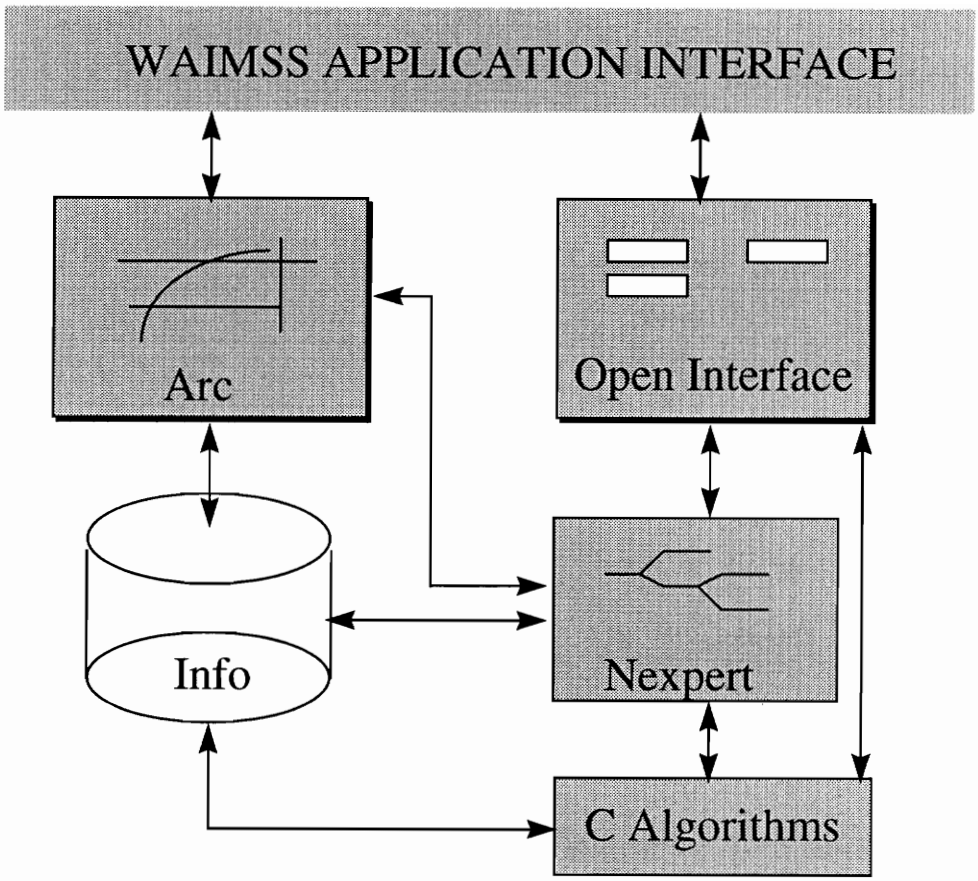

Figure 4.3 WAIMSS Application

4.3.1 DATA LEVEL INTEGRATION

An easy approach for data level integration is to employ data files in a format that both Arc/Info and Nexpert-Object can support. However, this would require writing data into a common file format before it can be accessed by either software. This operation is a time consuming process and is not suitable to employ such a method for real-time systems.

In order to permit a more direct data bridging, a C environment was implemented to permit direct access to the info file structure and Nexpert-Object variables. The Nexpert-Object expert system development package includes an application program interface, which permits developers to access Nexpert variables from C. In addition, Open Interface, the GUI development kit, comes with a toolkit of C libraries that can be used to read and write

widget attributes. C functions developed by Todd Stellhorn (ESRI) were used to allow Nexpert to directly read network information from the info files. This eliminated the otherwise tedious task of writing to a common file format.

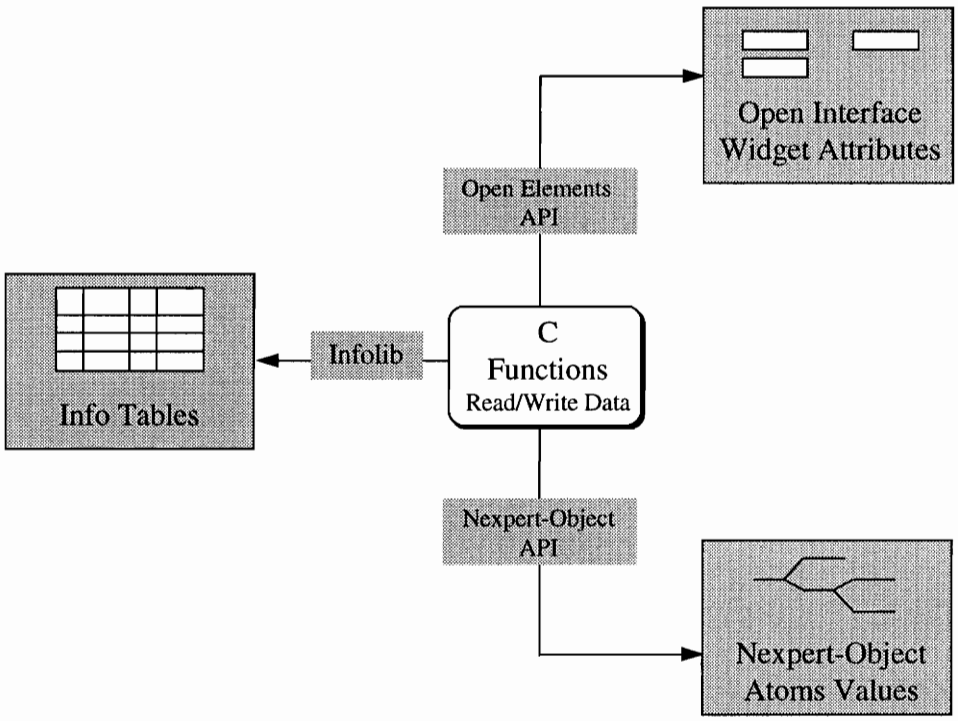

Figure 4.4 Data Level Integration of Nexpert and Arc/Info

Figure-4.4 shows the different bridges that were built for data level integration. Infolib is a light-weight library of C functions for accessing info files. It provides the ability to create, delete, open, read, write and close info files. The operations carried out using these functions include, reading and writing info file records to transfer network information to Nexpert during operations like delay and duration estimation.

4.3.2 COMMAND LEVEL INTEGRATION

A command level interface permits Nexpert-Object and Arc/Info to issue commands to each other and act upon the command issued by the other program. Although both packages permit the execution of external programs through system calls, only a command

interface can provide for the transfer of control between the two programs. This level of integration was achieved using Arc/Info's Inter Application Communication and by building an environment in C for controlling knowledge processing in Nexpert. The API for Nexpert makes it possible to build a controller for the inferencing and knowledge processing in C which could suggest parameter values and hypothesis directly into the inference engine. Figure 4.5 shows the overall concept behind the command level integration scheme.

Inter Application Communication (IAC) in Arc/Info enables software applications on remote or local machines to communicate with each other [20]. Based on Open Network Computing's (ONC) remote procedure call (RPC) protocol, IAC provides a way for external applications to request services of an Arc/Info process in server mode (AI-Server) and also makes it possible for an AML application to exploit the capabilities of other applications by being a client of those applications. An important component of IAC are the AI-Server and AI-Client shells. AI-Server provides a shell for creating a server to execute C functions and have these functions directly accessible from Arc/Info's AML-IAC interface.

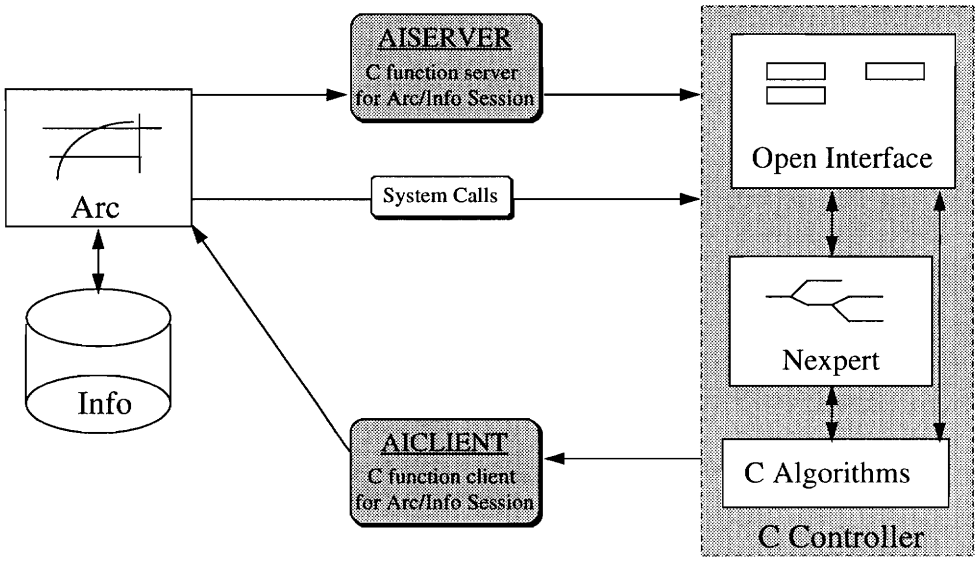

Figure 4.5 Command Level Integration of Nexpert and Arc/Info

This functionality is used to call Nexpert executables with AML variables as arguments. AI-Client on the other hand provides the ability to create client applications in C that can execute Arc/Info commands. This was used to write C functions that Nexpert-Object could access and execute Arc/Info commands by connecting to a Arc/Info server process and passing requests to that process.

4.4 MAP AND DATABASE DEVELOPMENT

An important consideration in the development of GIS based systems is the design and development of the spatial database. While most systems work on the "garbage in - garbage out" philosophy, GIS based systems conform to the "less than perfect in - nothing out" philisophy. Often database design and development take around fifty to sixty percent of the resources in any GIS based project. The database for WAIMSS was designed and developed using the Arc/Info data model.

A map and a related database are called a coverage in Arc/Info terminology. Based on the components of the database and the relationships established between them, the Arc/Info data model consists of five main levels of data organization - cartographic, georelational, coverage, feature class and topological [19].

1. **Cartographic Database:** A cartographic database organizes data using a related topological approach. The topology enables the use of two types of spatial data: locational data, to describe points, lines and areas, and attribute data for information about these features.
2. **Georelational Data Model:** This model allows the separation of geographic information into layers to represent each feature type such as roads, incident locations, hospital locations etc.. Spatial analysis with data in different layers is done by combining these layers when needed using utilities in Arc/Info.
3. **Coverage:** The coverage organizes data within a single map layer, hence describing one type of feature. A coverage is stored as a set of feature class files which describe actual

shape of the feature using nodes, lines and polygons. Geo-referenced locational information and the associated properties of the features are also stored at this level of data organization.

4. **Feature Class:** A feature class refers to the lowermost unit in the cartographic database. At this level, different features are treated as point, arcs, nodes, and polygons. A point is used to represent any feature that has zero area and length - e.g. bus stops, traffic signs, incident locations, etc. An arc is any line segment such as a network link with length as a property but no area. Nodes represent endpoints of arcs. Polygons are used to represent features with an area defined by a series of arcs. In addition to these basic features Arc/Info further allows the use of dynamic segmentation to define features called routes - linear feature made up of a series of arcs and events - instances an object occurring along the length of the route.
5. **Topological Data Structure:** This element of the data provides information on each feature relative to other features in the database. The topological structure ensures network(from-to) connectivity and adjacency information, which is often the basis of most spatial analyses.

The first step in the development of an accurate database for WAIMSS required the development of a well connected road network for the area. The entire road network in the area was modeled as a coverage and the attributes associated with each link were stored in a relational database in INFO. The following sections discuss briefly the steps taken during the development of the database.

4.4.1 DATA SOURCES

In order to expedite the database development process, a number of existing map databases for the application were investigated. In addition, it was felt that identifying a suitable already available database was necessary to ensure rapid prototyping of the system for different geographical locations. To this end the applications envisioned as a part of WAIMSS were analyzed to arrive at set of requirements for the map database. Given the

fact that alternate routing would be an important issue street centerline maps with accurate arc-node topology were required. To ensure this it was necessary to model divided highways as double line features with a clear representation of the on and off ramps. In addition, the datasets should have attribute information, proper road type classifications and street nomenclature. With these general requirements in mind, the 1:100,000 scale street centerline files from the following sources were evaluated for their suitability data sources were evaluated:

- U. S. Geological Survey's (USGS) Digital Line Graph (DLG) files.
- U. S. Census Bureau's TIGER/Line 1990 files
- Etak maps supplied by ETAK, Inc.

Digital line graphs (DLGs) are vector files containing line data, such as roads streams, digitized grom USGS topographic maps. The transportation and hydrography DLG files were highly accurate and topologically structured but lacked attribute information such as street names, highway types. The provided information regarding the spatial location of network links but lacked attribute information. In order to use these maps with WAIMSS it was necessary to go through an extremely tedious phase of creating the attributes for each network link.

TIGER/Line files are extracts of selected geographic and cartographic information from the Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Reference) System. These files on the other hand, had extensive attribute information, but lacked in topological consistency. The attribute information included a roadway classification that categorized streets into more than sixty different road types. Information of this kind could not be used effectively to arrive at a suitable transportation oriented classification (interstates, state highways, arterials etc.). In addition these maps had to be verified with base maps to ensure currentness and accuracy of the information.

Another major drawback of the above two sources was that, both represented divided highways as single line features. This was a major problem since it would require a number of enhancements in terms of from-to and to-from impedances and turning restrictions. The map database supplied by ETAK, Inc., on the other had satisfied most closely the requirements for roads. ETAK maps are based on TIGER/Line with the required enhancements to ensure topological consistency and accuracy. These maps contained double line divided highways, with the required attribute information on roads, railroads, address ranges and political geocodes. Since ETAK maps were originally designed for vehicle navigation, the roads are highly detailed and more accurate that those on the other map sources. In addition, the road classification included in the maps allowed an accurate depiction of different road types from a transportation perspective.

Given the relative advantages and the savings in the initial work required to build the database, ETAK maps were selected for the prototype development. The ready availability of this data for different locations also ensured the fact that WAIMSS could easily be ported to different geographic locations without additional development effort.

4.4.2 DATA CONVERSION AND PREPARATION

The ETAK maps were first converted into a format compatible with Arc/Info. The ETAKARC command was used to generate an Arc/Info coverage from the supplied files. The conversion process generates a coverage with the required features and an ACODE file in INFO with all the attribute information. The generated coverage is georeferenced by latitude and longitude coordinates. In order to facilitate the applications in WAIMSS these coordinates were projected to Universal Transverse Mercator coordinates with map units in meters. The topology of the coverage was them updated using the CLEAN command with the line and node options. The attributes from the ACODE file were then added to the arc attribute table (AAT) for the coverage, thus establishing a link between the map graphics and their attributes. The data conversion manual supplied with Arc/Info [23] provides a more detailed and step by step instructions for the above conversion process.

The ACODE file generated during the conversion process contained a number of attributes that are not useful in the context of the above system. These items were excluded from the database developed. The important attributes acquired from the ETAK supplied files are summarized in the table below

Table 4.1 Arc Attribute Table (AAT) Items Included from ETAK Maps.

Item Name	Description	Definition
COVER-ID	Unique user ID for each arc	4, 6, B
ETAK.ID	Etak ID number	8, 8, I
TYPE	The Etak record type	1, 1, C
CLASS	The road class	1, 1, C
NAME	Street or feature name	50, 50, C
ONEWAY	One-way code	1, 1, C

Following the conversion process, the coverage was edited in the ARCEDIT module of Arc/Info to correct any error and remove unnecessary features. The digital coverage was compared and verified with existing ADC (Alexandria) street maps of the area and some features that were not present were digitized. For most part, features were added since the supplied map came without any road features for Fairfax City. The major roads digitized in the vicinity of Fairfax City include two links on I-66, links on Lee Jackson Memorial Highway, US 29, Old Lee Highway, Jermantown Road, Picket Road and Chain Bridge Road. The links were digitized as one-way or two-way based on the information in the base maps.

In addition, the attribute table was modified to store information on impedances, historical flows, lane information and other parameters required by the system. The attributes added and their definitions are summarized in the table 4.2. Field data was not available for many of the items listed below. However in order to make a working system, it was necessary to have reasonable values for all these properties. To satisfy this requirement default values were assigned based on the roadway type assigned by ETAK. The default values assigned are discussed in the next section.

Table 4.2 Arc Attribute Table (AAT) Items added after Conversion

Item Name	Description	Definition
MAX_SPD	Maximum allowable speed in mph	2, 4, I
N_LANES	Number of lanes on link	2, 4, I
RT_SHOULDER	Right Shoulder Flag	1, 1, I
LT_SHOULDER	Left Shoulder Flag	1, 1, I
CAPLAN	Capacity per lane	5, 8, I
HS_VOLAN	Historical Volume	5, 8, I
CU_VOLAN	Current Volume	5, 8, I
SP_VOLAN	Special Event Volume	5, 8, I
BRIDGE	Bridge Flag	1, 1, I
FROM_TO_IMP	Dynamic From - To Impedance	8, 12, F
TO_FROM_IMP	Dynamic To - From Impedance	8, 12, F
PERM_FRTIMP	Static From - To Impedance	8, 12, F
PERM_TOFIMP	Static To - From Impedance	8, 12, F
TEMPSYM	Dynamic Display Symbol	3, 4, I
PERMSYM	Static Display Symbol	3, 4, I
STAT_RTNM	Static Route Associated with Link	10, 10, C

The travel time impedances for each link were then calculated dynamically based on the time activation of the system in order to account for changes in travel time based on traffic volumes. In the absence of current volume information the historical average volumes were used. In all cases, the interface provides tools to manually edit and change the defaults assigned, as and when data becomes available.

4.4.3 ROADWAY CLASSIFICATION AND DISPLAY CODES

As discussed above, the feature type in ETAK files stored in an item called CLASS. This classification was used to categorize the roads into interstates, on and off ramps, arterials etc. The different classes of features present in the originally converted coverage are shown in the table 4.3. Of the existing features, arcs that belonged to a class that were not pertinent to the domain of the problem were deleted from the coverage. This was done to reduce the size of the database and hence cut down on processing time. Arcs belonging to the feature classes 6, M, N, P, V, X, Y and Z were all deleted from the database.

Table 4.3 Feature Classes in Etak Files

CLASS	Description	No. of Records
0	High Speed Ramps	131
1	Interstates and Equivalent Roads	1363
2	Highway/Semi Limited Access	1288
3	Arterials	4483
4	Collector	2455
5	Lightduty/Local Roads	34548
6	Alley/Unpaved Roads	1964
8	Railroad	149
9	Low Speed Ramps	339
M	Restricted Access	0
N	Positionally Inaccurate Features	0
P	Political Boundaries	1918
S	Shorelines	360
V	Driveway	2
X	Ferry Line	0
Y or Z	Artificial boundaries at the geographic limit of the database.	31

Shorelines and railroads were however retained in order to improve the map displays aesthetically and serve as points of reference for users and operators of the system. The classification codes were then used to decide on the default values for link data that was not available. Table 4.4 summarizes the default values assigned for each link class.

Table 4.4 Link Classes and their Default Attributes

CLASS. Description	MAX_SPD (MPH)	N_LANES	CAPLAN (ADT/24)	BRIDGE
0. High Speed Ramps	45	2	1800	1
1. Interstates and Equivalent Roads	65	4,2*	2400	0
2. Highway/Semi Limited Access	55	4,2*	1800	0
3. Arterials	55	4,2*	1800	0
4. Collector	45	4,2*	1800	0
5. Lightduty/Local Roads	30	2	1200	0
8. Railroad	1	0	0	0
9. Low Speed Ramps	25	1	900	1
S. Shorelines	1	0	0	0

*4 lanes if road is represented as single line and 2 if road is represented as a double line

To reflect the classification of the roadways, each link type was assigned a color symbol that reflected its class. The color coding was done with the idea of improving the display and presenting the operator with a more organized set of information. Table 4.5 shows the color codes and line types assigned for each road class.

Table 4.5 Display Codes

CLASS. Description	CODE	R, G, B	SIZE	TYPE
0. High Speed Ramps	2	0, 0, 255	.005	Wide
1. Interstates and Equivalent Roads	3	0, 0, 255	.015	Wide
2. Highway/Semi Limited Access	4	100, 180, 255	.015	Wide
3. Arterials	5	200, 150, 0	.010	Wide
4. Collector	5	200, 150, 0	.010	Wide
5. Lightduty/Local Roads	1	255, 255, 255	.000	Wide
8. Railroad	87	0, 255, 0	.10	Marker4
9. Low Speed Ramps	2	0, 0, 255	.005	Wide
S. Shorelines	7	0, 255, 255	.000	Wide
-. Eliminated Links	11	255, 0, 0	.025	Wide
-. Static Routes	12	255, 255, 0	.045	Wide
-. Dynamic Routes	14	0, 255, 0	.045	Wide
-. Incident Link	13	255, 0, 0	.35	Marker1576

A custom color code file was created using the LINEEDIT facility in Arc/Info. The red, green and blue (RGB) percentages assigned for each color code are maintained in this file called linecolor.dat. The static colors associated with each link were assigned to the "PERMSYM" item in the AAT and used for display. The dynamic color codes like link elimination color or incident link were assigned through the software code to reflect user inputs and system outputs.

4.4.4 TURN TABLE GENERATION

Preparing a road network database for routing applications requires the generation of a turn table that identifies every possible turn from one link to another and computes the angle and azimuth of each turn. This turn information is used during the generation of a least-impedance route. The turn table information for the Fairfax County road network was

generated using commands in the NETWORK module of Arc/Info. The turn information is stored in INFO in a table referenced by the name of the coverage and a .TRN extension.

The turn table however, does not initially include any measurements for the impedance associated with each turn. These have to be assigned manually based on the nature of the turn at each intersection. For this purpose an additional item, called TURN_IMP, was added to the table. Based on the nature of the turn, default values were assigned for each turn. Table 4.6 presents the defaults used in for to specify each turn.

Table 4.6 Default Turn Impedances

Type of Turn	Impedance in Minutes
Right Turns on Surface Streets	.17
Left Turns on Surface Streets	.50
Zero Impedance Turns (High Speed Ramps)	0
Prohibited Turns	-1

For some specific intersections turn impedance values were manually entered. The values stored as the turn impedance were then used as inputs for the route finding algorithm in Arc/Info, for alternate route generation.

4.4.5 STATIC ROUTE DATABASE

Current practices in diversion in the area involve the use of pre-defined or static alternate routes for a possible incident on each freeway link. The Northern Virginia Freeway Incident Management Operating Manual [1] documents these recommended alternate routes with information on the ramps to be closed and locations where police personnel and detour signs are likely to be needed (Figure 4.6)

These pre-defined alternate routing plans were incorporated into the database as a route system in Arc/Info. Routes define linear features with similar attributes and a collection of routes with a common system of measurement is called a route system. The operating manual specified around 40 alternate routes for different freeway links in the Fairfax County

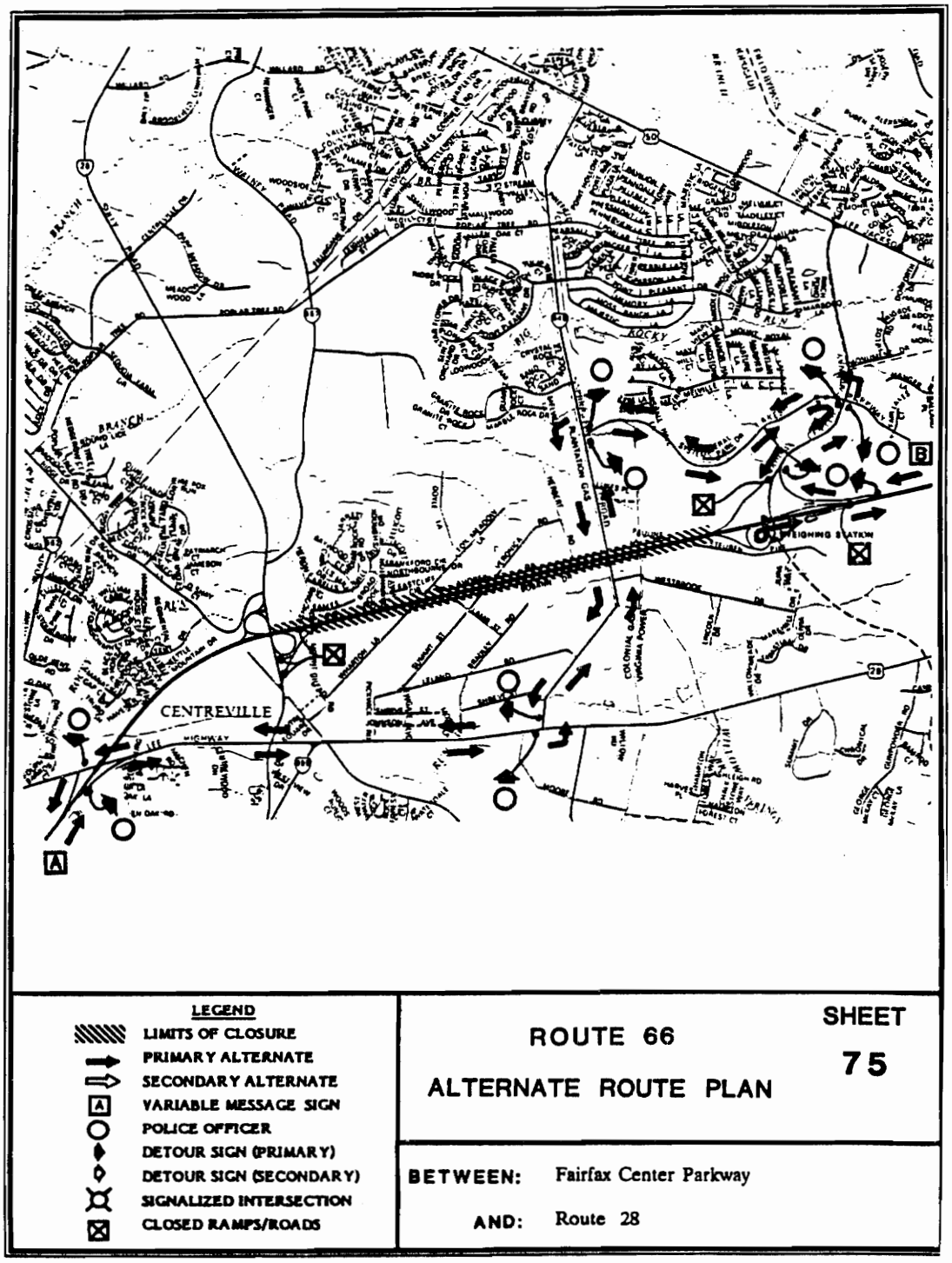

Figure 4.6 A Pre-Defined (Static) Alternate Route

(Source: Virginia Department of Transportation (VDOT), Northern Virginia Freeway Management Team Operating Manual - A Regional Plan for Traffic Management on Northern Virginia Freeways, April 1990)

area. These routes were defined in the database in a route system called HISTRT. A unique identifier and a name were assigned to each route and were used to relate each route with the appropriate freeway link(s). Using this relate key users can query alternate routes based on their names in the operating manual or through the current incident link.

In addition, an interface was also developed to allow operators to modify input or delete alternate route plans in the static route database. The functionality and use of this component of the prototype system is discussed in later sections of this chapter.

4.5 RULE BASE DEVELOPMENT

Implementing the decision support modules discussed in chapter three required the development of adequate rule bases for each module. Knowledge acquired from experts from the field and previous studies [10] was represented as rules using the Nexpert-Object expert system shell. A forward chaining inferencing mechanism was then employed to use these rules in providing appropriate suggestions.

The sections below summarize the effort that went into the rule base development for each module. It is important to note here that this component of the prototype development is not within the scope of the research objectives outlined in chapter one. Work in this area was carried out by other members of the project team. Appropriate references have been cited where necessary. However, interfacing the rules with the GIS database and creating a complete working system was accomplished as a part of the study. In addition, during the course of the integration the network generator module was enhanced by adding components for impact area definition and route generation.

4.5.1 DURATION ESTIMATION

The rule base developed for this module attempts to predict reasonably, the duration over which the effects of the incident will last. Accurate estimation of incident duration is vital

for effective management of incidents by providing information that can be used to determine proper incident management strategies. The estimated incident duration can be used to determine possible delays that is likely to be caused by the incident, to assess the severity of the incident, to decide whether traffic diversion is needed or not, and to provide meaningful delay information to drivers. A methodology was developed to estimate incident duration in Northern Virginia based in the extensive analysis of incident data [24].

Data collected from incident clearance operations in the Northern Virginia area was used to develop the knowledge base. Information of over 5000 incidents in Northern Virginia area was gathered in a two phase data collection effort. A detailed analysis of the data by severity of incidents, operational factors, roadway types, and environmental factors was performed to determine significant factors affecting the incident clearance times. As a result of the study, incident duration was found to be mainly determined by incident type severity, and clearance characteristics. The study also showed that it was not possible to establish linear relationships between attributes and incident duration. Among the other approaches considered, the estimation approach was selected as a prediction mechanism for duration. Estimation trees provided a simple representation of the incident data set that was be used for categorizing different incidents and using the classification for estimating duration.

The estimation/decision trees were then constructed for each incident type using the tree structured regression method. Figure 4.7 shows one such tree for property damage incidents. Similar trees were constructed for other incident types and were implemented as a combination of Nexpert rules and C algorithms.

4.5.2 DELAY CALCULATION

This component of decision support was implemented entirely in C. This module aimed at making reasonable estimated of the delays associated with an incident. Queuing models were employed to calculate delay based on the estimated duration of the incident. The module currently employs deterministic queuing theory for delay prediction. An incident is

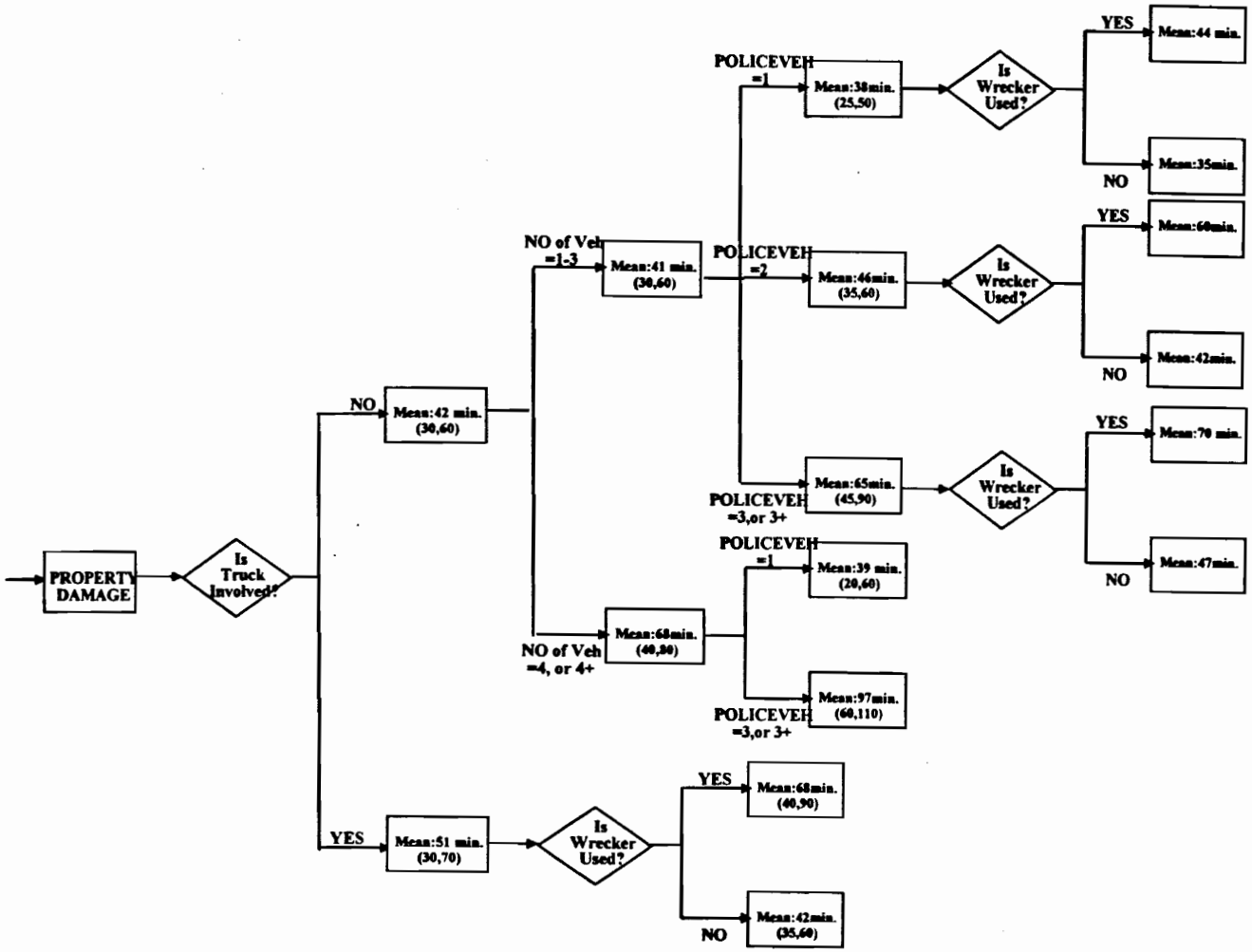

Figure 4.7 Duration Estimation Tree for Property Damage Incidents

(Source: Ozbay K., Hobeika A., Zhang Y., Estimation of Duration of Incidents in Northern Virginia, Paper Submitted for presentation and publication at the 77th annual meeting of the Transportation Research Board, January 1997)

modeled as a temporary blockage on the freeway which reduces the capacity. The resulting delay due to the reduction in capacity is calculated as shown below.

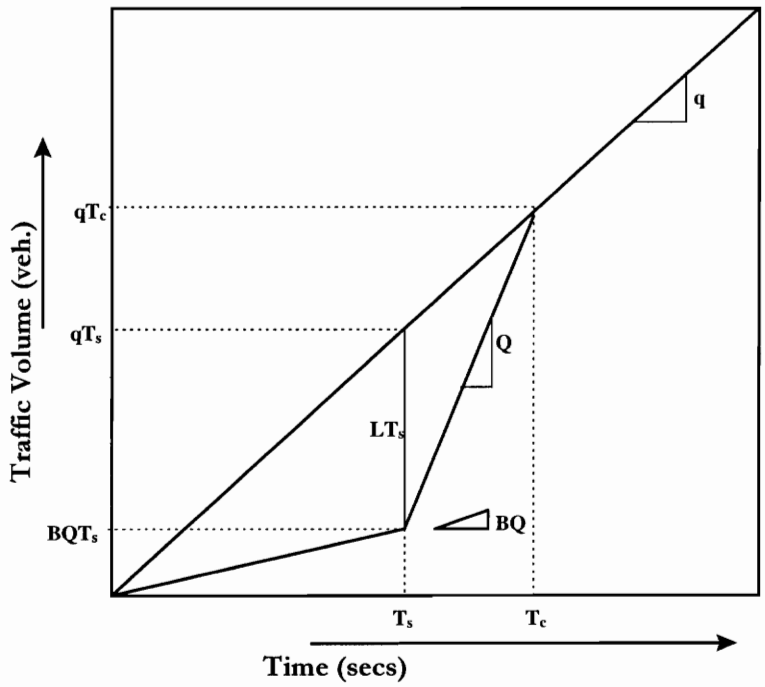

Figure 4.8 Graphical Representation of the Deterministic Queing Model

From figure 4.8 the resulting delay can be caculated as:

$$D = 0.5*LT_s*T_c \qquad \& \qquad W = D/(q*T_c)$$

where

D	= Total traffic delay (veh - sec)
W	= Average delay per vehicle (sec)
T_s	= Duration of incident (sec)
T_c	= Duration of congestion (sec)
LT_s	= Number delayed at Time T_s (veh)
LT_c	= Number delayed at Time T_c (veh)
q	= Traffic demand (veh/sec)
Q	= Highway capacity (veh/sec)
B	= Loss in capacity
L	= Average number of vehicles delayed (veh)

The required inputs to this module like link flows and capacities are directly obtained from the GIS database using the data bridge between Arc/Info and Nexpert.

4.5.3 NETWORK GENERATOR

This component of the rule base was developed to provide decision support for diversion planning and real-time alternate route generation. In most part, the knowledge acquisition and representation was done as a part of an earlier study [10]. The main focus of this module is to determine if diversion is necessary and then develop appropriate diversion plans that take into account current conditions on the network links. The inferencing process follows a three step procedure in determining a diversion route-impact area definition, link elimination and route generation.

1. **Impact Area Definition:** In order to reduce the processing load, an impact area is defined around the incident. The incident impact area is the area around the incident which forms the search space to find alternate routes. For an incident of high severity, the most beneficial diversion strategy may call for origin and termination points of diversion that are quite a distance away from the site of the incident. Thus, for such a case, the incident impact area needs to be large enough to be able to permit the flow of very high volumes of traffic from the origin point(s) to the destination point(s) of the diversion. For an incident of lesser severity, it may suffice to have a relatively smaller search area, for the diversion strategy. The impact area was defined as a function of four factors - expected incident delay, traffic congestion levels, and incident severity. Table 4.7 presents the heuristics employed to determine the impact area:

Table 4.7 Heuristics for Determining the Incident Impact Area

Incident Severity	Expected Delay (veh. hrs.)	Incident Impact Area	
		Major Axis	Minor Axis.
0	0 - 1000	3 miles (peak hour) 2 miles (non-peak)	2 miles (peak hour) 1.5 miles (non-peak)
1	1000 - 2000	5 miles (peak hour) 4 miles (non-peak)	3.5 miles (peak hour) 3 miles (non-peak)
2	2000 - 5000	8 miles (peak hour) 6 miles (non-peak)	6 miles (peak hour) 4 miles (non-peak)
3	5000+	12 miles (peak hour) 9 miles (non-peak)	9 miles (peak hour) 6 miles (non-peak)

The heuristics developed for the impact area module determination account for these factors in two stages. The first set of heuristics use the incident delay to estimate an incident impact area. This set, also includes heuristics relating to traffic congestion levels around the incident area that suggest different impact areas for peak and non-peak conditions. The next set of rules revise the estimate generated from the previous based on the incident type and severity. Based on the size of the area determined, a subset of the network is created be the GIS , which is then used by the knowledge base for further processing.

2. **Link Elimination:** The next set of heuristics examine each link in the impact area to check if they are feasible for diversion. The links are examined with respect to a wide array of decision factors that include both link attributes and external factors like weather and jurisdictional issues. These factors are used to determine the elimination status of a link. For example, links with low capacity and high levels of existing traffic volumes are eliminated and not considered for diversion.
3. **Route Generation:** A route generation module is then employed using the route-finding algorithm in Arc/Info to dynamically generate the most feasible alternate route. Prior to running the route-finding algorithm, all the eliminated links are assigned very high values of impedance and hence excluded from being a part of the alternate route. The dynamically generated alternate route is then used in comparison with the available static route plan in the GIS database. Linking this module with the GIS required complete two-way transfer of both data and control between the two software environments of Arc/Info and Nexpert-Object.

4.5.4 RESPONSE MODULE

The response module is employed to finalize the response plan based on the delay, duration and current information on resource availability. Expert system rules were used to classify the severity of the incident occurrence based on the input parameters and to indicate the equipment required to clear the incident.

The module is still under development and current efforts are focused on the development of macros for dynamically checking a resource availability at various dispatch locations around the incident and select a set of feasible locations [25]. The routing is based on minimal response time for each dispatch involved in the total response. Priority is given to response from fire and rescue and police, in light of the hazard to human life involved. This module also contains rules for media notification of incident when required. This includes HAR(Highway Advisory Radio), TV and radio broadcasts, changeable message signs (CMS), control locations, etc.. Upon execution of a selected response plan, this module automatically resets itself for the next response request.

Other major enhancements planned for this module include the provision of emergency telephone numbers and points of contact to the operators and personnel involved.

4.6 SYSTEM FUNCTIONALITY AND INTERFACE

The section discusses the actual working of the software and the different options and tools provided in the interface. WAIMSS provides a integrated interface to the user for the expert system and the GIS. Transparent to the user, the two software environments interact and exchange information to produce meaningful analyses and outputs for each incident scenario.

User-friendly interfaces have been created for each application using the Open Interface toolkit and Arc/Info AML. Menus were developed using the Open Interface toolkit in cases where Arc/Info AML lacked the required widgets. The focus during the development effort, was to provide the end-users a unified way of interacting with the computer in general and the WAIMSS applications in particular, without having to know the internal architecture of either the computer of the applications. Attempts were also made to create an intuitive interface so that operators could learn and work with the system with minimal training and prior knowledge of the applications. In most part, the options on the interface are mouse and menu driven. Keyboard interaction has been kept to minimum, and wherever possible

choices are provided as selectable item lists. Minimal use is made of input forms to eliminate mistakes in entering information.

The software is started using a startup script at the console prompt. This script starts up Arc/Info opens up an initial map display screen and options menu (Figure 4.9). From here on the software functions from the ARCPLOT shell in Arc/Info and all user interaction is through the graphical user interface.

The title on the options menu (Traffic Management Center - TMC) indicates the location where the system is being used. During the course of development a parallel and less powerful application was developed for a simulated Police Control Center. The site specific applications for the Police Control Center were in most part a subset of the functionality available through the TMC system. Hence, the sections below discuss the interface design and the functionality with respect the TMC system. Other aspects such as the interaction between the two systems during incident response are discussed in the next chapter.

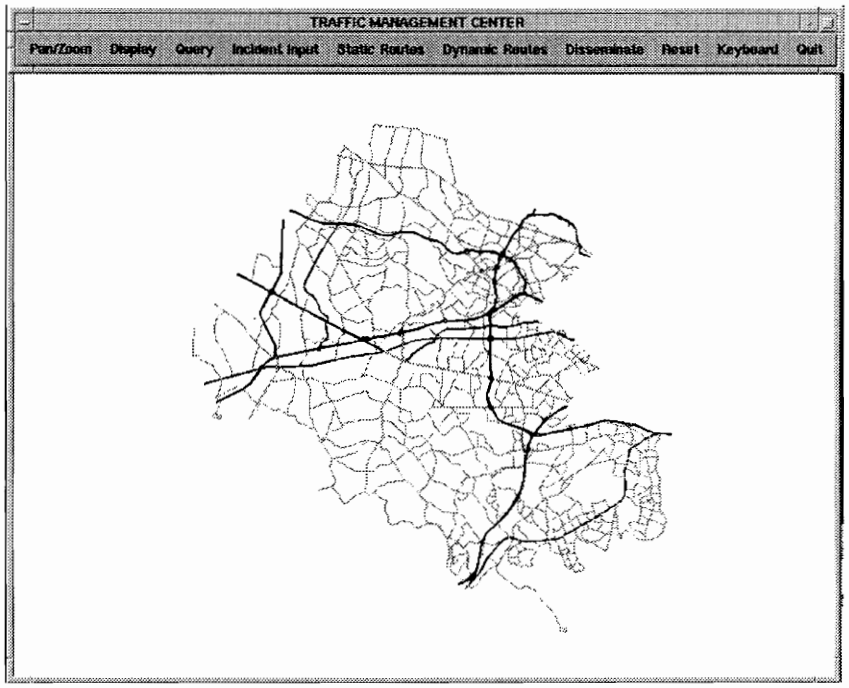

Figure 4.9 Opening Map Display Screen and Options Menu

The options menu in the opening screen is the common entry point for the applications developed for the prototype. It presents an ordered collection of the available functions. Figure 4.10 provides an overview of the available functions for each pulldown. Each option either directly performs the requested action or triggers other menus that sequentially prompt the operator for information required for that operation. The sections below discuss the functions accessed from this main pulldown menu in greater detail.

4.6.1 MAP DISPLAY AND QUERY

The first three options on the pulldown - Pan/Zoom, Display and Query, provide the basic display and querying utilities for the system. Options on the Pan/Zoom pulldown allow the user to zoom in and out of areas of interest on the map display. The user could also choose to move to different sections of the map using the "Pan" option without changing the scale the display, or reset the display to entire extent of the map using the "Fullview" option.

The Display pulldown allows the user to selectively view road types on the map. The "Major Roads" option clear the screen and displays the interstates and state highways while the "Local Roads" and the "All Road" options can be used to surface streets alone or all the roads in the network. The Querying option allows the operator to interactively select links and view its attributes. Properties such as the name, length, road type, maximum speed and capacity of the selected link are returned to the user in through an AML dialog.

4.6.2 INCIDENT INPUT

This pulldown provides options to input information about an incident. Non-locational data such as the incident type and weather conditions are entered using the "Incident Characteristics" option. On selecting this option, the user is presented with a dialog box with fields for entering the incident characteristics (Figure 4.11).

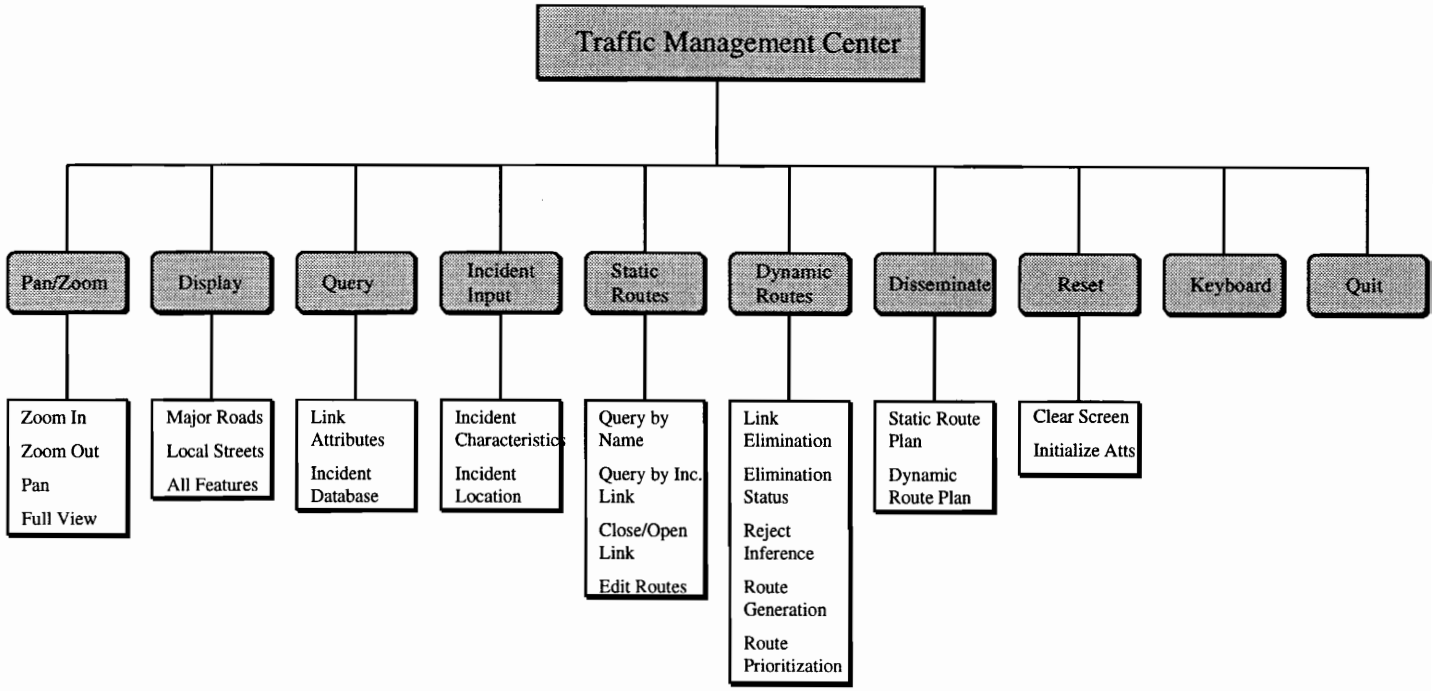

Figure 4.10 Options Accessible from the Main Pulldown Menu

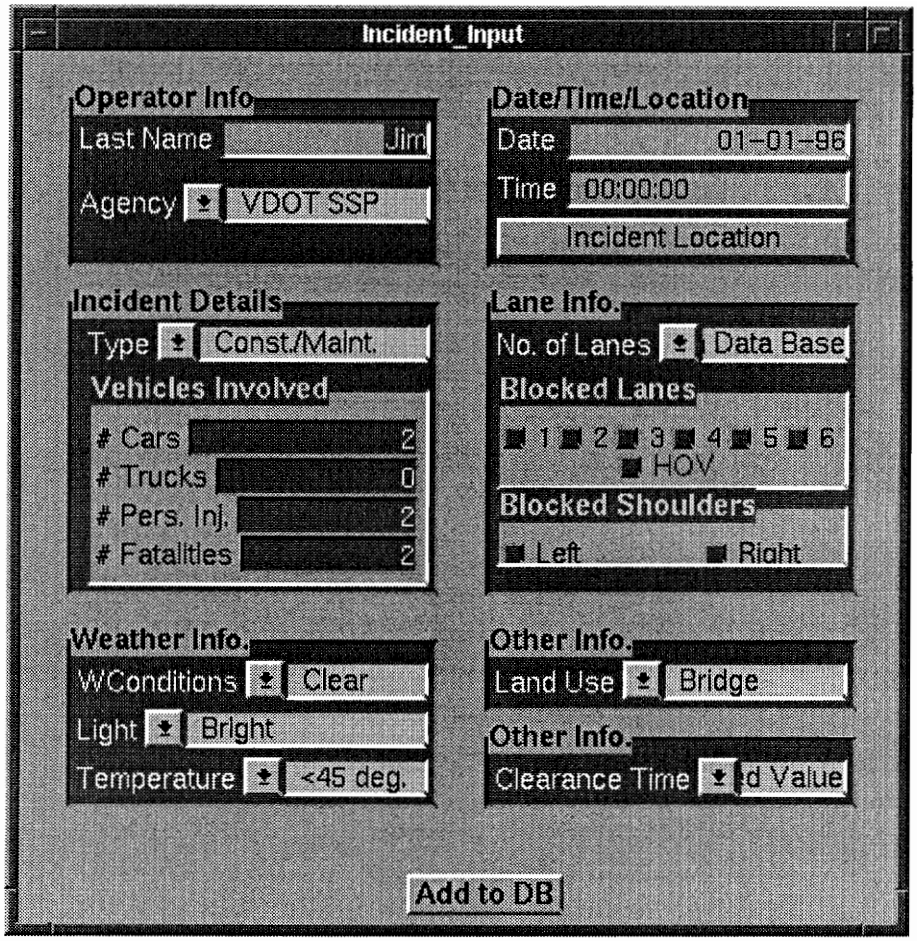

Figure 4.11 Incident Characteristics Input Menu

The information entered is saved in the database for later use by the rule base in Nexpert-Object. The other option on this pulldown allows the user to input the actual location of the incident. Inputting the location of the incident involves interactively selecting the link on which the incident occurred. Once the incident link is selected the display symbol on the link is changed and a search area is determined. The display is updated by zooming into the search area. If the incident is verified, then the displays on all sites running the system are updated accordingly at all sites running the system. This ensures that all the agencies involved have current information on the status of the network. Verification of the incident input, also results in trigering the duration and delay estimation modules of the expert system. These modules are followed by the generation of a preliminary response plan that

provides the operator with summary statistics and suggestions about the available strategies. Figure 4.12 shows the dialog used to provide response information the operator.

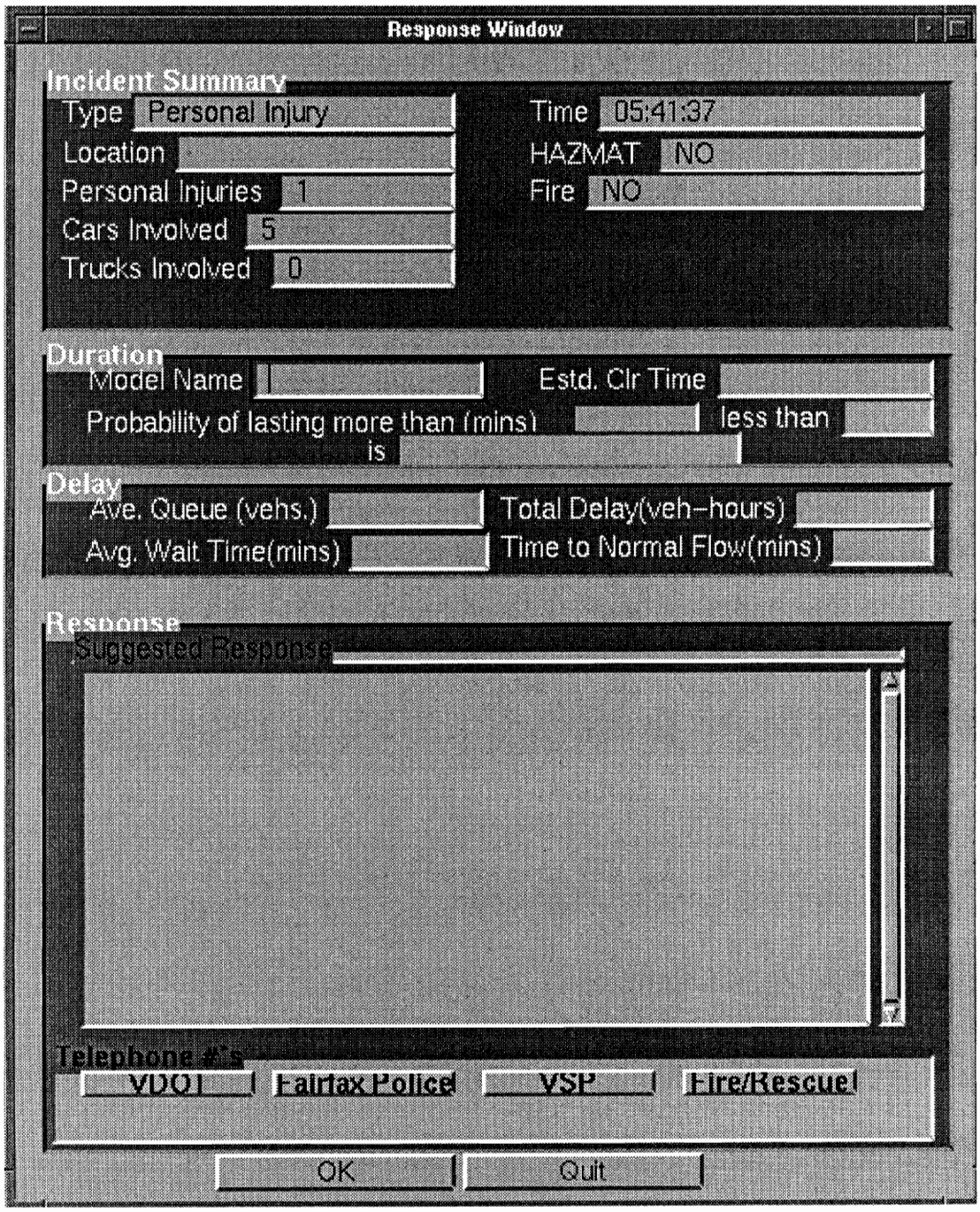

Figure 4.12 Response Screen

An important suggestion offered by the system at this stage of incident response, is the need to divert vehicles. Based on the average vehicle delay and the total delays associated with the incident the response module recommends the need divert traffic.

4.6.3 STATIC ROUTES

This pulldown allows the users to query the static route database, interactively close or open links in the network and access the editing interface for modifying the static route database. The query facility allows the user to view the pre-defined routes in the database by their names or by the link on which the incident has occurred. On selecting the second option the available static route for the incident link is read off the database and drawn on the map display.

Closing or opening links on the network involves changing the impedances on the link to reflect current information about the link such as on-going construction activity etc. The "Edit Routes" option opens up an arcedit session with another pulldown from where a user access options to add, modify or delete pre-defined routes from the static routes database. Details about this element of the interface are presented in a latter section.

4.6.4 DYNAMIC ROUTES

Based on the recommendation made by the response module, it may be necessary to divert traffic onto an alternate route. In some cases a predefined alternate routing plan may not be available or suitable for diversion. Under such a scenario can access the options in the "Dynamic Routes" pulldown and generate a most feasible alternate route in real-time. The "Link Elimination" option connects to the Network Generator rule base and identifies links in the impact area that can be used for diversion. The rule base heuristically eliminates links that are not feasible for diversion based on real-time conditions such as existing congestion on the link, special events, weather conditions etc.. Selecting this option opens up a dialog

(Figure 4.13) where the user can enter threshold values that will be used to decide the elimination status of a link.

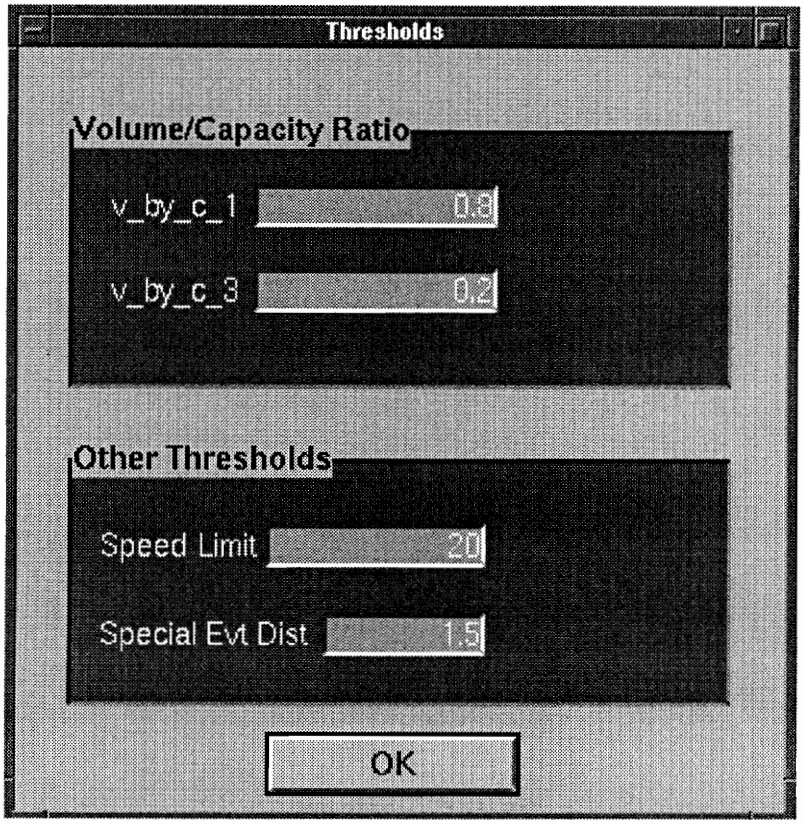

Figure 4.13 Link Elimination Thresholds

Based on the thresholds input and the attribute information in the link the rule base eliminates unusable links and directly resets their impedance and the symbol associated with their display. All eliminated links are now displayed on the map in red. At this point the operator may query the reasons for elimination using the "Elimination Status" option and/or override the expert system decision using the "Reject Inference" option. The "Route Generation" option uses Arc/Info's route finding algorithm to generate a feasible alternate route using links in the search area that were not eliminated. As a part of the dynamic route generation the user has to interactively define the starting and ending points for diversion.

4.6.5 INFORMATION DISSEMINATION

This pulldown provides the user with options to communicate with site specific applications running at other agencies. At the present stage of development, it provides utilities to disseminate information about the static or dynamic alternate route plans that were adopted for diversion. Selecting the options on this pulldown automatically updates the display on all the currently active systems at remote sites with the selected diversion plan. The alternate route selected for implementation is drawn on the all display and a message is sent indicating the selection.

4.6.6 EDIT INTERFACE

In order to maintain the static route database a menu driven interface was built in ARCEDIT to support operations to add, delete or modify static route plans. The entire process of editing the static routes database was automated through this interface. Figure 4.14 provides an overview of the main pull down menu and the available options. The first two options on the pulldown - Display and Pan/Zoom, provide the required map display features. These are similar in function to the features described earlier except for the fact that they work in the ARCEDIT shell. The "Static Route" pulldown provides utilities to interactively select a set of links from the network and define them as a new route, or append them to an existing route. In addition, existing route plans can be further modified or deleted by removing links or deleting the entire route definition from the database.

The "Point Event" option provides options to add suggested locations for events such as police personnel, detour signs etc. along each route. Another important functionality in this interface is the ability to associate a particular route with a set of incident links on the network. This association facilitates the querying of existing alternate routes given an incident on a particular link. The other options on this pulldown provide routine functions like drawing the selected routes, clearing the screen and saving the edits made to the database.

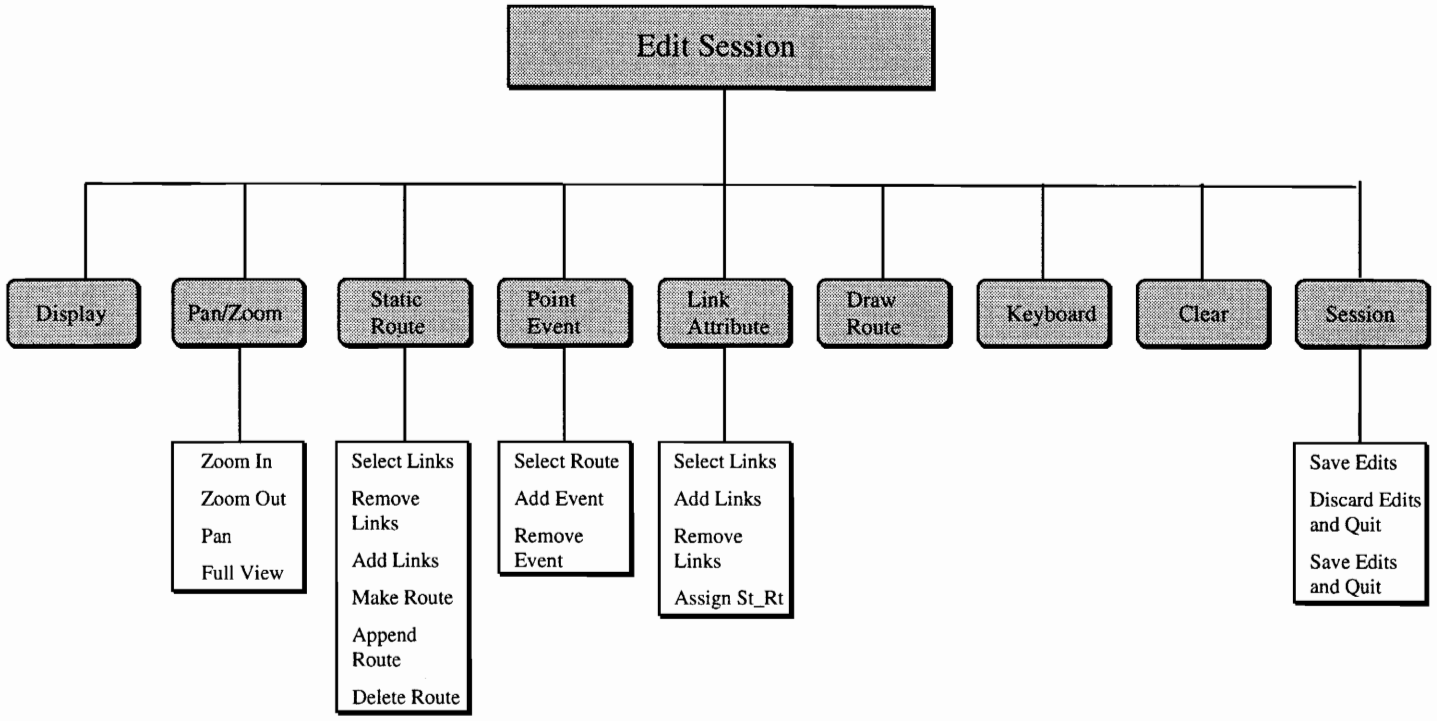

Figure 4.14 Options Accessible from the Edit Session Pulldown

In conclusion, the sections in this chapter discussed the effort that went into the development of a working prototype of the Expert-GIS system. A brief overview of the functionality achieved through the prototype is also provided. The next chapter examines the working of the system with historical incident data and discusses its applicability to large scale incidents.

5. APPLICATION

This chapter provides a summary of typical working scenarios with WAIMSS. In addition it examines the working of the system with respect to historical incident data and evaluates the validity and usefulness of the response suggestions.

5.1 CASE STUDIES

Data from a number of historical incidents was used to validate the response suggestions offered by the prototype system. Validation of the output from the rule base was performed by the individual studies referred to in the section rule base development in chapter four. The main focus in the evaluation effort here is to ensure the proper working of the system for different incident scenarios and the accuracy of the database in terms of network connectivity and attribute information.

Figure 5.1 shows a typical incident management scenario while working with WAIMSS. As a first step in the process the incident is first detected and reported to Police and its characteristics and location are entered into the system at the Police Control Center. This triggers a messaging system that transfers this information to other agencies and requests verification of the incident. In the context, WAIMSS this verification is provided by the Traffic Management Center. If the incident report is found to be a false alarm all applications are reset and the current status of the incident report is conveyed to all other systems. If the incident report is found to be true, a preliminary response plan is immediately generated using available information on the incident and the network characteristics. This plan is refined and modified as and when more information on the incident is available.

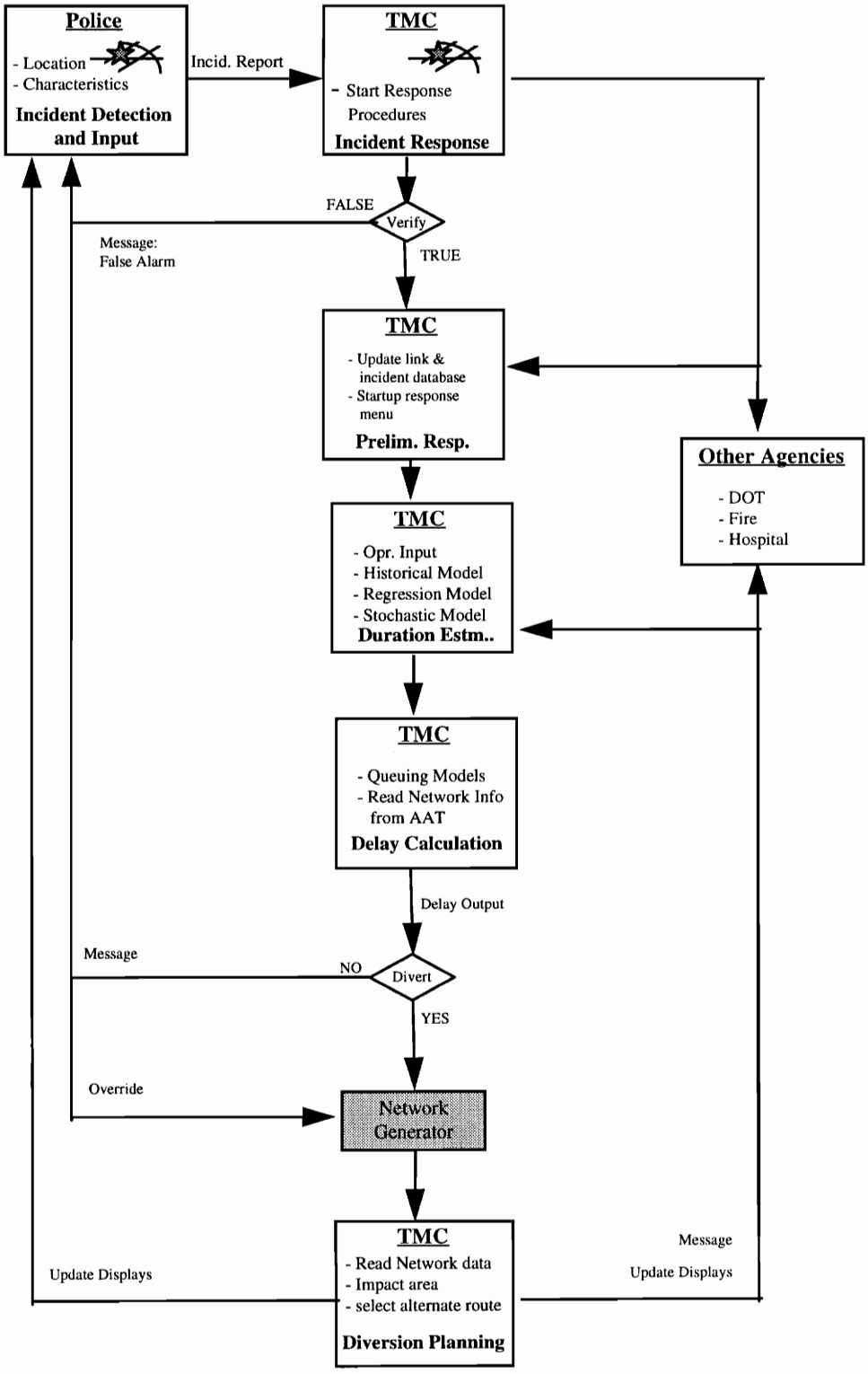

Figure 5.1 A Typical Incident Management Scenario with WAIMSS.

A major component of the preliminary response plan is identifying the agencies and provide an estimate of the resources required to clear the incident. This step also starts the duration estimation and delay calculation modules. Based on the computed delay the initial need to divert is determined. The delay and duration values are constantly updated as more and more current information becomes available. If the need to divert is determined, the operator checks the static route database for usable predefined alternate route plans. If a usable static route plan is not found, the network generator is employed to eliminate unusable links and generate an alternate route plan in real-time.

The entire process is iterative and based on the currently available information the suggested strategies are revised and updated. At the present stage of development, the system depends on the operator to a large extent for obtaining current information. However, as ITS technologies are implemented the system will be able to directly access information like link flows through sensors on the road network. In addition, the design incorporates the need to communicate with changeable message signs to disseminate information to motorists.

In most of the tests with the historical incident data, this scenario of operator-system interaction was emulated. Working with the system for major incidents however, required a greater interaction on the part of the operator, while minor incidents that didn't require diversion plans were almost completely automated. These tests also helped in checking the accuracy and consistency of the data. For e.g. a number of turn table errors were discovered at this stage of the testing. Dynamically generated routes would often take invalid turns on to freeway links from the surface streets. These errors were corrected my manually selecting these turns and assigning them an impedance of -1 to prohibit the invalid turn. The sections below provide sample cases of the test conducted.

5.1.1 INCIDENT CASE I

This incident case uses an incident involving a disabled tractor-trailer to evaluate the response suggested by WAIMSS. The main characteristics of the incident are summarized in Table 5.1

Table 5.1 Incident Characteristics - Case I

Characteristic	Details
Location	I-66 Eastbound @ Exit 60
Type	Disabled Vehicle
Vehicles Involved	1 tractor trailer
Time of Occurrence	6:00 AM - 10:00 AM, 04/20/94
Weather	Clear; Temperature between 45 and 85
Lane Closure	2 rightmost lanes out of 4 closed; Right Shoulder Closed

The actual clearance time reported for this incident on the data collection form was an approximate estimate of 30 minutes. The clearance time estimated by WAIMSS for this incident was 27 minutes. Such an estimate is close enough for most practical uses of the system. Based on the estimated duration the resulting average delays for each vehicle were found to be extremely low and hence diversion was not recommended. This suggested response also satisfies the general rule of thumb of not diverting traffic if the incident duration is less than two hours.

At this stage the operator may choose to reject this suggestion and go opt for diverting traffic if a predefined alternate route plan exists and can be readily implemented. Figure 5.2 shows the possible diversion route that could have been adopted if required.

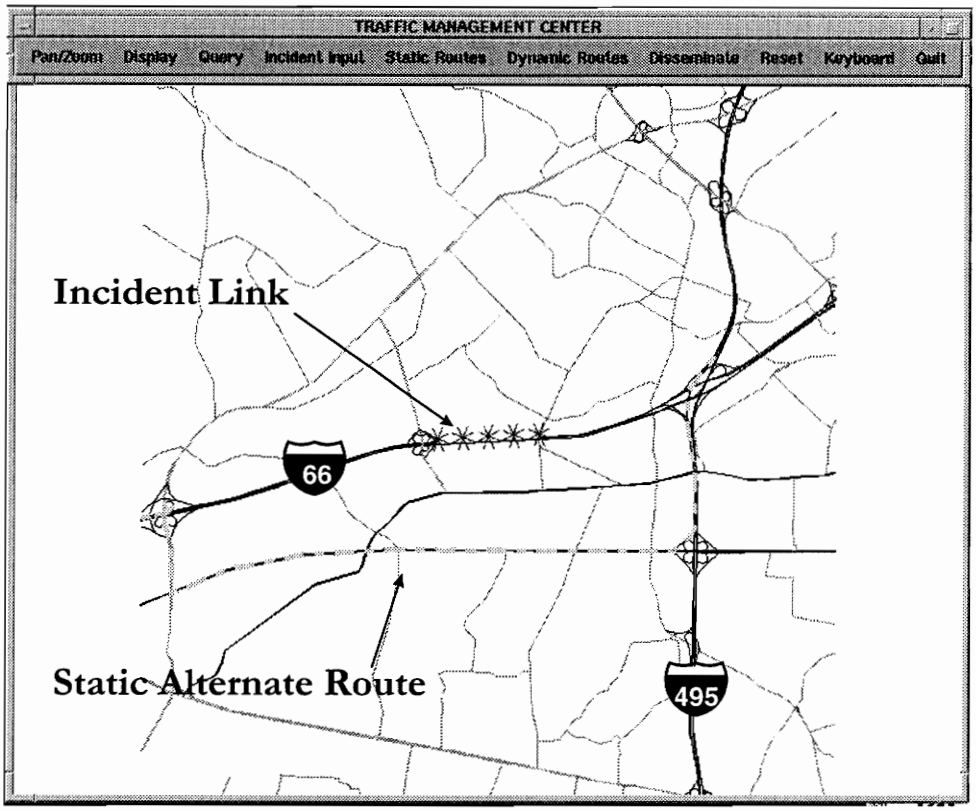

Figure 5.2 Static Diversion Route Selected for Incident Case I

5.1.2 INCIDENT CASE II

This incident case uses a property damage incident involving a truck. The main characteristics of the incident are summarized in Table 5.1

Table 5.2 Incident Characteristics - Case II

Characteristic	Details
Location	I-66 Eastbound @ Exit 53
Type	Property Damage, Personal Injury
Vehicles Involved	1 Truck
Time of Occurrence	12:00 NOON - 2:00 PM, 04/12/94
Weather	Clear; Temperature between 45 and 85
Lane Closure	2 rightmost lanes out of 4 closed; Right Shoulder Closed
Wreckers Used	1

The actual clearance time reported for this incident was an approximate estimate of 60 minutes. The clearance time estimated by WAIMSS for this incident was 68 minutes. This estimate is a little on the conservative side. This, however, was expected given the severity of the incident. This factor also influenced the decision to divert. Diversion was recommended although the clearance time was less than two hours.

However, upon querying the static route database it was found that the predefined route plan could not be used due to construction activity in the area. One of the links in the predefined plan was under maintenance work and hence could not be used for diverting high volumes of traffic from the interstate. The links under construction were then eliminated from the network and a second alternate routing plan was generated in real time. Figure 5.3 shows the dynamic diversion route generated.

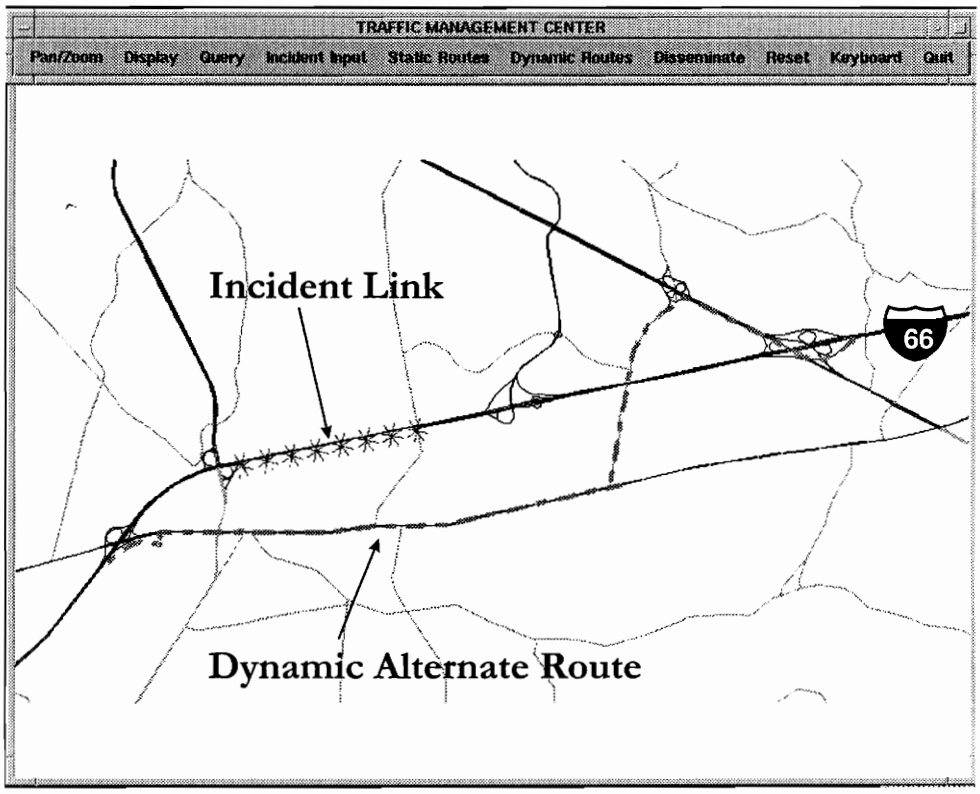

Figure 5.3 Dynamic Diversion Route Generated for Incident Case II

In conclusion, the prototype system provides a number of functions that can be readily used for incident management. With the implementation of ITS technologies, a number of the functions discussed above can be automated and carried out with little or no operator interaction. The open architecture adopted also allows for easy integration of support modules developed in the future. The next chapter discusses these details along with the scope for future work.

6. CONCLUSIONS & RECOMMENDATIONS

6.1 CONCLUSIONS

The Group Decision Support System (GDSS) architecture of WAIMSS makes it one of the first support systems for incident management that recognize the cooperative nature of the entire incident management process. In providing decision support it addresses both the substance of decision making and the various individual and agency level interactions that take place.

Its design as a fully integrated Expert-GIS system further allows it to exploit the spatial data handling capabilities of the GIS and the inferencing capabilities of an expert system and hence comprehensively deal with the spatial and temporal nature of problem. WAIMSS is a collection of several modules, each providing a specific incident management capability to the system. The integration of these components provides a cumulative effect that enhances the ability of operators to better handle incidents on the country's busiest roadways. A modular capability is provided to enable use of portions of the system to stand alone in smaller regions and to increase the flexibility for continued improvement of the overall system. The selection of the modules, based on their functions and not necessarily on the sequence of processes alone adds flexibility to the system. The architecture presented provides a responsive system that can significantly improve incident management operations across the country.

It is important to point out here that the intent of the design and development effort is more cautious than the recognized decision support system. It is not intended to replace the human problem solvers with computer based tools, but rather to use the system to extend the capacity of human decision makers operating under conditions of complexity and stress. Nor is the goal of the system to model the problem solving process of expert decision

makers in the field as undertaken in other policy areas. In incident management, the problems are too complicated and ill-structured to adopt this approach.

The underlying assumption of this system is that by making relevant information available to operating personnel in a timely and interactive mode, the system is likely to increase the power of the decision makers to make appropriate decisions. As the breadth and scope of ITS technologies continue to expand, the amount to incoming information and the complexity of both the networks and response functions will make it increasingly difficult, if not impossible, for human operators to function effectively without automated assistance.

WAIMSS addresses this issue and aims at reducing the cognitive overload on the involved personnel through appropriate information and decision support. Use of the system will reduce the personnel involvement needed to focus on true operational problems, permit rapid development of optimal and consistent response plans, and facilitate coordination among all relevant agencies, thereby reducing delays associated with non-recurring congestion.

The prototype development effort helped in identifying areas of concern before full-scale deployment of the system. A major concern was the lack of current information on link attributes such as number of lanes and traffic volumes and the location and availability of resources and equipment. This information was not available from any of the data sources evaluated as part of the project. It might be necessary to initiate a data collection effort to fill this gap. In addition, it is important to maintain the currency and accuracy of the information in the database once the system has been installed.

Another concern in the development effort was the lack of a clear delineation of the roles and responsibilities of the agencies involved. This delineation is necessary for the development of agency specific databases and applications. At its present stage of development, WAIMSS works for a hypothetical traffic management center and a police control center. The functionality for the applications at these two applications was decided

arbitrarily and does not conform to an established protocol. Future deployment of the system will require this specification of roles and responsibilities to avoid conflicts and confusion during the process of managing an incident.

6.2 FUTURE DIRECTIONS

WAIMSS provides an ideal platform for further work in the area of incident management. Future research in this area should aim to improve expert system modules and the GIS database. As a first step it is very important that the system be deployed at a few test agencies. This will provide the required feedback for deciding on the required areas of improvement. Porting the application to the PC platform is another issue that should be looked into. PC based solutions are relatively less expensive to implement and have a quicker learning curve that UNIX based systems. In this context, ESRI's ArcView 3.0 provides and ideal GIS platform for development. Porting to a PC platform will expedite the implementation of the system and will even make it possible to put WAIMSS on every desktop.

In order to ensure rapid prototyping of the system for different geographic locations it would be a good idea to add data conversion and import utilities to the software. This will automate the process of using WAIMSS across different areas and significantly reduce the effort that goes into creating the database for the incident management applications. As a part of this task, efforts should also be made towards creating an interface for importing data from common transportation packages like MINUTP, QRS II etc. Since most transportation agencies maintain their data in these packages, this functionality is vital for successful deployment of the system.

Additions to the GIS interface, include the ability to create plots and reports from the information in the database. Also, there is need to dynamically generate two or more disjoint paths during the dynamic route generation option. This facility allows the personnel to divert traffic further upstream of the incident, instead of using the shortest available path

across the incident link. The process of selecting the starting and ending points of diversion route can also be automated using heuristics in the rule base. Improvements could also be made to the impact area definition algorithm, which currently defines the impact area as rectangular area. For freeway incidents, the impact area could be defined as ellipse with the freeway aligned along its major axis.

Currently, most of the information used in the generation of the response strategies is static in nature. With the widespread deployment of ITS technologies, this will no longer be the case. Since the architecture of the system supports easy integration with roadway sensors and changeable messages signs, efforts should be enhance the prototype in this direction with a set of test sensors and message signs.

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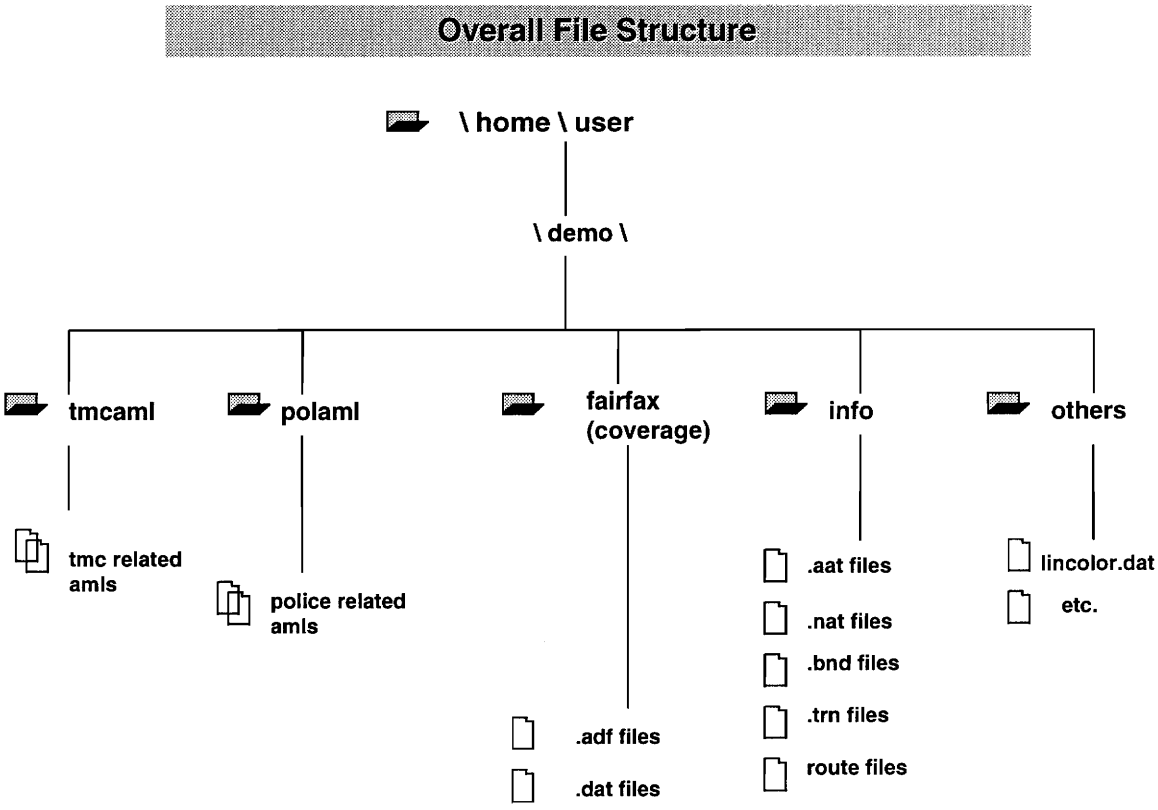
APPENDIX

A.
SOFTWARE ORGANIZATION



B.
ARCPLOT AMLS

```
/*  main menu
/*  Creates the main pulldown menu for the ARCPLOT session.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date :  June 95
/*  Project :  Incident Management
/*  Arguments :  tmc_stat


1
Feature
   'Major Roads'     &run tmcaml/major_roads.aml
   'Local Roads'     &run tmcaml/local_streets.aml
   'All Roads'       &run tmcaml/all_features.aml
View
   'Zoom In'    &run tmcaml/zi
   'Zoom Out'   &run tmcaml/zo
    Pan         &run tmcaml/pan
   'Full View'  &run tmcaml/fullvi
   'Zoom In Using Measure' &r tmcaml/zi_meas.aml
Query
   'Attribute List'             &run tmcaml/qlist
   'Attribute Pickup'           &run tmcaml/qitem
   'Elimination Status'         &run tmcaml/elchk
   'Incident Database'          &run tmcaml/indb
EditSession
    'Road Network'      &run tmcaml/edit_session.aml
    'Response Centers'  &run tmcaml/edit_centers.aml
IncInput
   'InfoForm'               &r tmcaml/incid_char.aml
   'Location(link)'         &r tmcaml/incid_link.aml
   'Location(milepost)'     &r tmcaml/incid_meas.aml

Response
     Response                  &run tmcaml/dura.aml
     'Display Response Centers'     &run tmcaml/centers.aml
StaRoute
   'Query by Name'       &r tmcaml/selrt_name.aml
   'Query by Inc. Link'  &r tmcaml/selrt_inclk.aml
   'Close/Open Link'     &r tmcaml/cl_open.aml
   'Edit Routes'         &r tmcaml/edit_session.aml
DynRoute
   'Link Elimination'              &run tmcaml/link_elim.aml
   'Elimination Status'            &run tmcaml/elchk
   'Explanation'                   &run tmcaml/explan.aml
   'Reject Inference'              &run tmcaml/reject
   'Routing(mouse)'                &run tmcaml/rt_gen.aml
   'Routing(milepost)'              &r   tmcaml/rt_gen_m.aml
   'Route Prioritization'          &run tmcaml/rt_prio.aml
Communications
```

```
   'Send Static Diversion Plan'       &r tmcaml/bcastmes_statrt.aml
   'Send Dynamic Diversion Plan'      &r tmcaml/bcastmes_dynart.aml
   'Read Mail from POL'               &r tmcaml/read_mail.aml
   'Write to POL'                     &r tmcaml/write.aml
   'Mail to POL'                      &r tmcaml/send.aml
Reset
   'Clear Screen'            Clear
   'Initialize Atts.'        &r polaml/init.aml
Keyboard           &tty
Quit     &s tmc_stat = [IACCLOSE] ; quit
```

```
/*  disp.aml*
/*  Startup aml; initializes display environment & calls the main menu.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : tmc_stat, .curr_cov


/*  SET STATION
&stat 9999
display 9999 size 650 900  position 0 0 screen 600 0

/*  OPEN TMC SESSION AS IN SERVER MODE
&s tmc_stat = [IACOPEN tmc_cf]

/*  CALL ARCPLOT AND FIX INITIAL MAP SETTINGS
arcplot
lineset ~arvind/demo/color.lin

/*  OBTAIN NAME OF COVERAGE FROM USER
&messages &popup
&s .curr_cov = [response 'Input Coverage Name' fairfax]
&if ^ [exists %.curr_cov% -cover] &then &do
  &ty Coverage Not Found, Using Default Coverage (FAIRFAX)
  &s .curr_cov = fairfax
&end
&messages &on

/*  INITIALIZE AND FIX MAP SETTINGS
&r tmcaml/init.aml
mape %.curr_cov%
mapposition cen cen
mapunits meters

/*  RUN THE MACRO TO CREATE PULLDOWN MENUS
&menu tmcaml/main &stripe 'TRAFFIC MANAGEMENT CENTER'
&return
```

```
/*  major_roads.aml
/*  Selects and displays the major roads - highways and arterials.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none
```

```
clearselect
reselect %.curr_cov% arc class = '5'
nselect %.curr_cov% arc
arclines %.curr_cov% tempsym
&return

/*  local_streets.aml
/*  Selects and displays the local streets in the coverage.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


clearselect
reselect %.curr_cov% arc class = '5'
aselect %.curr_cov% arc class = 'S'
arclines %.curr_cov% tempsym
&return
```

```
/*  all_features.aml
/*  Displays all the features in the coverage
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


clearselect
arclines %.curr_cov% tempsym
&return
```

```
/*  zi.aml
/*  Zooms in repeatedly around specified points.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : mx, .xlow, .ylow, .xhigh, .yhigh, .dx, .dy


&messages &popup
&type any key to zoom in, 9 to exit
&messages &on
&label top
&getp &map
&if %pnt$key% = 9 &then &return
&type zooming in...

/*  EXTRACT THE MAPEXTENT COORDINATES
&s mx = [show mapextent]
&s .xlow  = [extract 1 %mx%]
&s .ylow  = [extract 2 %mx%]
&s .xhigh = [extract 3 %mx%]
```

```
&s .yhigh = [extract 4 %mx%]
&s .dx = %.xhigh% - %.xlow%
&s .dy = %.yhigh% - %.ylow%

/*  ADJUST MAPEXTENT WITH THE SPECIFIED POINT AS THE
/*  CENTER OF HALF THE ORIGINAL EXTENT
&s .xl %pnt$x% - %.dx% / 4
&s .yl %pnt$y% - %.dy% / 4
&s .xh %pnt$x% + %.dx% / 4
&s .yh %pnt$y% + %.dy% / 4

/*DEFINE NEW  MAPEXTENT AND REDRAW ARCS
mapextent %.xl% %.yl% %.xh% %.yh%
clear
arclines %.curr_cov% tempsym
&goto top
```

```
/*  zo.aml
/*  Zooms out repeatedly around specified points.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : mx, .xlow, .xhigh, .yhigh, .ylow, .dx, .dy


&messages &popup
&type any key to zoom out, 9 to exit
&messages &on
&label top
&getp &map
&if %pnt$key% = 9 &then &return
&type zooming out...

/*  EXTRACT THE MAPEXTENT COORDINATES
&s mx = [show mapextent]
&s .xlow  = [extract 1 %mx%]
&s .ylow  = [extract 2 %mx%]
&s .xhigh = [extract 3 %mx%]
&s .yhigh = [extract 4 %mx%]
&s .dx = %.xhigh% - %.xlow%
&s .dy = %.yhigh% - %.ylow%

/*  ADJUST MAPEXTENT WITH THE SPECIFIED POINT AS THE
/*  CENTER OF TWICE THE ORIGINAL EXTENT
&s .xl %pnt$x% - %.dx%
&s .yl %pnt$y% - %.dy%
&s .xh %pnt$x% + %.dx%
&s .yh %pnt$y% + %.dy%

/*DEFINE NEW MAPEXTENT AND REDRAW ARCS
mapextent %.xl% %.yl% %.xh% %.yh%
clear
arclines %.curr_cov% tempsym
&goto top
```

```
/*  pan.aml
/*  Pans across a coverage using software mapextent.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : mx, .xlow, .xlow, .xhigh, .yhigh, .dx, .dy


&messages &popup
&type any key to pan, 9 to exit
&messages &on
&label top
&getp &map
&if %pnt$key% = 9 &then &return
&type panning...

/*  EXTRACT THE MAPEXTENT COORDINATES
&s mx = [show mapextent]
&s .xlow  = [extract 1 %mx%]
&s .ylow  = [extract 2 %mx%]
&s .xhigh = [extract 3 %mx%]
&s .yhigh = [extract 4 %mx%]
&s .dx = %.xhigh% - %.xlow%
&s .dy = %.yhigh% - %.ylow%

/*  ADJUST MAPEXTENT TO MAKE THE SPECIFIED POINT THE
/*  CENTER OF THE EXTENT
&s dx2 %.dx% / 2
&s dy2 %.dy% / 2
&s .xl %pnt$x% - %dx2%
&s .xh %pnt$x% + %dx2%
&s .yl %pnt$y% - %dy2%
&s .yh %pnt$y% + %dy2%

/*  DEFINE NEW MAPEXTENT AND REDRAW ARCS
clear
mapextent %.xl% %.yl% %.xh% %.yh%
arclines %.curr_cov% tempsym
&goto top
```

```
/*  fullvi.aml
/*  Displays the selected features for entire coverage.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


mape %.curr_cov%
clear
arclines %.curr_cov% tempsym
&return
```

```
/*  qlist.aml
```

```
/*  To query link attributes by interactively specifying the link.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


/*  IDENTIFY FUNCTION IN ARCPLOT
&messages &popup
&fullscreen &popup
&type Select Link
identify %.curr_cov% arc * NAME LENGTH CLASS MAX_SPD N_LANES CAPLAN
HS_VOLAN
&messages &on
&fullscreen &on
&return
```

```
/*  qitem.aml
/*  Allows user to pick up an attribute from choices for a particular
/*  link.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : Jan 95
/*  Project :  Incident Management
/*  Arguments : .curr_cov


/*  IDENTIFY FUNCTION IN ARCPLOT
clearselect
&messages &popup
&fullscreen &popup
&s item = [quote [getchoice FNODE# TNODE# LPOLY# RPOLY# LENGTH FAIRFAX#
FAIRFAX-ID CLASS NAME ONEWAY MAX_SPD N_LANES RT_SHOULDER LT_SHOULDER
CAPLAN HS_VOLAN CU_VOLAN SP_VOLAN BRIDGE FROM_TO_IMP TO_FROM_IMP
PERM_FRTIMP PERM_TOFIMP TEMPSYM PERMSYMSTAT_RTNM -PROMPT 'Choose a
Type']]

identify %.curr_cov% arc * %item%
&messages &on
&fullscreen &on
&return
```

```
/*  elchk.aml
/*  Checks the elimination status of the link.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : status


clearselect
&messages &popup
&type Select Link
&messages &on
```

```
/*  INTERACTIVELY SELECT LINK AND EXTRACT THE STATUS
reselect %.curr_cov% arc one *
&s status = [show select %.curr_cov% arc 1 item tempsym]

&messages &popup
&if %status% = 2  or %status% = 6 &then &do
  &type Link Eliminated due to:
&end
&else &do
  &type  This Link is not Eliminated
&end
&messages &on

&return
```

```
/*  indb.aml
/*  Incident database (Still under construction).
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


&messages &popup
&type Under Construction
&messages &on
&return
```

```
/*  edit_session.aml
/*  Opens a new thread and runs aml to start arcedit session.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


&thread &create editses &run tmcaml/aesyscall.aml
&return
```

```
/*  incid_char.aml
/*  Opens the incident input screen as a background process.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


&sys xterm -e ~arvind/demo/inc_inp.scr &
&return
```

```
/*  incid_link.aml
/*  Allows interactive input of incident location and defines.
```

```
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : .id, fnode, tnode, fn_x, fn_y, tn_x, tn_y, inc_x,
/*  inc_y, inc_char_file, I, inc_type, imapct_area_width, xmin, xmax,
/*  ymin, ymax

/*  SEARCH AREA FOR THE CREATION OF A SUBSET FILE - SUBSET.AAT
/*  SUBSEQUENTLY DOWNLOADS THE INCIDENT LINK DATA INTO A ASCII FILE
/*  USES THE AML - download.aml - TO EXPORT THROUGH INFO THE SELECTED /*
RECORD

&messages &popup
searchtolerance automatic
&type Input the Location of the Incident
&messages &on

/*  SELECT INCIDENT LINK AND EXTRACT ID, FNODE AND TNODE
clearselect
reselect %.curr_cov% arc one *
&s .id = [show select %.curr_cov% arc 1 item %.curr_cov%#]
&s fnode = [show select %.curr_cov% arc 1 item fnode#]
&s tnode = [show select %.curr_cov% arc 1 item tnode#]

/*  SET SYMBOL FOR INCIDENT LINK AND UPDATE IMPEDANCE
reselect %.curr_cov%.aat info %.curr_cov%# = %.id%
calculate %.curr_cov%.aat info tempsym = 13
calculate %.curr_cov%.aat info from_to_imp = 1000000
calculate %.curr_cov%.aat info to_from_imp = 1000000

/*  GET MIDPOINT OF INCIDENT LINK
clearsel
reselect %.curr_cov%.nat info %.curr_cov%# = %fnode%
&s fn_x = [show select %.curr_cov%.nat info 1 item x-coord]
&s fn_y = [show select %.curr_cov%.nat info 1 item y-coord]
clearsel
reselect %.curr_cov%.nat info %.curr_cov%# = %tnode%
&s tn_x = [show select %.curr_cov%.nat info 1 item x-coord]
&s tn_y = [show select %.curr_cov%.nat info 1 item y-coord]

/*  CALCULATE MIDPOINT OF LINK
&s inc_x = ( %fn_x% + %tn_x% ) / 2
&s inc_y = ( %fn_y% + %tn_y% ) / 2

/*  WRITE INCIDENT LOCATION TO LOCATION INFO FILE (INLOC)
clearselect
calculate inloc info X_LOC = %inc_x%
calculate inloc info Y_LOC = %inc_y%

/*  READ THE ASCII FILE WITH INCIDENT CHARACTERISTICS TO DEFINE IMPACT
AREA
/*  NAME OF THE FILE ~arvind/demo/incident_data_text_file
&s inc_char_file = [open ~arvind/demo/incident_data_text_file openstat -
read]
&s i = 1
&do &while %i% < 6
  &s inc_type = [read %inc_char_file% openstat]
```

```
  &s i = %i% + 1
&end
&s inc_type = [unquote %inc_type%]
&if [upcase [quote %inc_type% ] ] cn 'HAZMAT' &then &do
  &s impact_area_width = 25000
&end
&else &do
  &s impact_area_width = 20000
&end

/*DEFINE IMPACT AREA
&s xmin = %inc_x% - %impact_area_width% / 2
&s xmax = %inc_x% + %impact_area_width% / 2
&s ymin = %inc_y% - %impact_area_width% / 2
&s ymax = %inc_y% + %impact_area_width% / 2

/*  SELECT FEATURES IN SEARCH AREA AND CREATE SUBSET INFO FILE
clearselect
reselect %.curr_cov% arc class = '5'
nselect %.curr_cov% arc
reselect %.curr_cov% arc box %xmin% %ymin% %xmax% %ymax%
infofile %.curr_cov% arc subset.aat # init

/*  DEFINE NEW MAPEXTENT AND ZOOM IN
mape %xmin% %ymin% %xmax% %ymax%
clear
clearselect
arclines %.curr_cov% tempsym

&r tmcaml/download.aml
&return
```

```
/*  incid_meas.aml
/*  Locates the incident  according to a user-defined measure.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : rt#, lnk#, id, fnode, tnode, fn_x, fn_y, tn_x, tn_y,
/*  inc_x, inc_y, inc_char_file, i, inc_type, imapct_area_width, xmin,
/*  xmax, ymin, ymax


&s rt_sys_nm = [quote [getchoice INTERSTATE USHIGHWAY LOCAL HISTRT -
PROMPT 'Choose A Route System']]
/* &s curr_rtid = [response 'Enter the Route ID']
&messages &popup
&s curr_rtnm = [quote [upcase [response 'Enter the Route Name']]]
&s rt_meas = [response 'Enter the Route Measure']
&messages &on
/*   reselect   %.curr_cov%.rat[unquote   %rt_sys_nm%]   info   [unquote
%rt_sys_nm%]-id = %curr_rtid%

reselect %.curr_cov%.rat[unquote %rt_sys_nm%] info name = %curr_rtnm%
&s rt# = [show select %.curr_cov%.rat[unquote %rt_sys_nm%] info 1 item
[unquote %rt_sys_nm%]#]
clearsel
```

```
reselect %.curr_cov%.sec[unquote %rt_sys_nm%] info routelink# = %rt#%
and t-meas >= %rt_meas% and f-meas <= %rt_meas%
&s lnk# = [show select %.curr_cov%.sec[unquote %rt_sys_nm%] info 1 item
ARCLINK#]

clearsel

reselect %.curr_cov%.aat info  %.curr_cov%# = %lnk#%

&s .id = [show select %.curr_cov%.aat info  1 item %.curr_cov%-id]

calculate %.curr_cov%.aat info tempsym = 13
calculate %.curr_cov%.aat info from_to_imp = 1000000
calculate %.curr_cov%.aat info to_from_imp = 1000000


&s tn# = [show select %.curr_cov%.aat info 1 item TNODE#]
&s fn# = [show select %.curr_cov%.aat info 1 item FNODE#]
reselect  %.curr_cov%.nat info  %.curr_cov%# = %tn#%
&s fn_x = [show select %.curr_cov%.nat info 1 item x-coord]
&s fn_y = [show select %.curr_cov%.nat info 1 item y-coord]
clearsel
reselect  %.curr_cov%.nat info %.curr_cov%# = %fn#%
&s tn_x = [show select %.curr_cov%.nat info 1 item x-coord]
&s tn_y = [show select %.curr_cov%.nat info 1 item y-coord]
&s c_x = ( %fn_x% + %tn_x% ) / 2
&s c_y = ( %fn_y% + %tn_y% ) / 2

clearselect
calculate inloc info X_LOC = %c_x%
calculate inloc info Y_LOC = %c_y%

&s inc_char_file = [open ~arvind/demo/incident_data_text_file openstat -
read]
&s i = 1
&do &while %i% < 6
  &s inc_type = [read %inc_char_file% openstat]
  &s i = %i% + 1
&end
&s inc_type = [unquote %inc_type%]
&if [upcase [quote %inc_type% ] ] cn 'HAZMAT' &then &do
  &s reach = 25000
&end
&else &do
  &s reach = 20000
&end


&s xmin = %c_x% - %reach% / 2
&s xmax = %c_x% + %reach% / 2
&s ymin = %c_y% - %reach% / 2
&s ymax = %c_y% + %reach% / 2
mape %xmin% %ymin% %xmax% %ymax%
clear
clearselect
arclines %.curr_cov% tempsym
```

```
&r tmcaml/download.aml

&return
```

```
/*  dura.aml
/*  Makes a system call for the response module.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


&sys Response
&return
```

```
/*  selrt_name.aml
/*  Selects a static route for display by name.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : sel_rt


&messages &popup
&s sel_rt = [response 'Enter the Name of the Route']
&messages &on
&s sel_rt = [quote [upcase [value sel_rt]]]
clearsel
reselect %.curr_cov% route.histrt NAME = %sel_rt%
routelines %.curr_cov% histrt 12
eventsource add point event_so %.curr_cov%.events info ordered histrt#
histrt# measure
eventmarkers %.curr_cov% histrt event_so type event.lut

&return
```

```
/*  selrt_inclk.aml
/*  Displays static alternate route based on incident link.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : sel_rt


clearsel
reselect %.curr_cov%.aat info %.curr_cov%# = %.id%
&s sel_rt = [show select %.curr_cov%.aat info 1  item STAT_RTNM]
&if [quote %sel_rt%] cn 'NA' &then &do
  &messages &popup
  &ty No Existing Alternate Route Plan
  &messages &on
&end
&else &do
  reselect %.curr_cov% route.histrt name = [quote [value sel_rt]]
```

```
  routelines %.curr_cov% histrt 12
&end
&return
```

```
/*  cl_open.aml
/*  Close or open links on the static routes.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : id, option, .curr_cov


clearselect
&messages &popup
&type Select Link
&messages &on

/*  SELECT LINK AND EXTRACT ID
reselect %.curr_cov% arc one *
&s id = [show select %.curr_cov% arc 1 item %.curr_cov%#]
reselect %.curr_cov%.aat info %.curr_cov%# = %id%


/*  SYMBOL AND UPDATE IMPEDANCE ACCORDING TO RESPONSE
&messages &popup
&s option = [response 'Link Status - Close/Open']

&if [quote [upcase %option%]] cn 'CLOSE' &then &do
  calculate %.curr_cov%.aat info tempsym = 11
  calculate %.curr_cov%.aat info from_to_imp = 1000000
  calculate %.curr_cov%.aat info to_from_imp = 1000000
  &type Link Closed, Redrawing Map
&end
&else &do
  calculate %.curr_cov%.aat info tempsym = permsym
  calculate %.curr_cov%.aat info from_to_imp = perm_frtimp
  calculate %.curr_cov%.aat info to_from_imp = perm_tofimp
  &type Link Opened, Redrawing Map
&end
&messages &on

clearselect
clear
arclines %.curr_cov% tempsym
&return
```

```
/*  edit_session.aml
/*  Opens a new thread and runs aml to start arcedit session.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


&thread &create editses &run tmcaml/aesyscall.aml
```

```
&return
```

```
/*  link_elim.aml
/*  Calls the nextpert executable to eliminate links.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


&messages &popup
&type Starting the Nexpert Inference Engine
&messages &on

/*  SYSTEM CALL TO EXECUTE NETGEN WITH FL103 AND SUBSET.AAT AS ARGS
&sys      Netgen      1      /home/arvind/demo//info:arc:%.curr_cov%.aat
/home/arvind/demo//info:arc:subset.aat

/*  SET IMPEDANCE AND SYMBOL OF INCIDENT LINK
clearselect
reselect %.curr_cov%.aat info %.curr_cov%# = %.id%
calculate %.curr_cov%.aat info tempsym = 13
calculate %.curr_cov%.aat info from_to_imp = 1000000
calculate %.curr_cov%.aat info to_from_imp = 1000000

/*  UPDATE IMPEDANCES OF ELIMINATED LINKS
clearselect
reselect %.curr_cov%.aat info tempsym = 11
calculate %.curr_cov%.aat info from_to_imp = 1000000
calculate %.curr_cov%.aat info to_from_imp = 1000000

clearselect
clear
arclines %.curr_cov% tempsym
&return
```

```
/*  elchk.aml
/*  Checks the elimination status of the link.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : status


clearselect
&messages &popup
&type Select Link
&messages &on

/*  INTERACTIVELY SELECT LINK AND EXTRACT THE STATUS
reselect %.curr_cov% arc one *
&s status = [show select %.curr_cov% arc 1 item tempsym]

&messages &popup
&if %status% = 2  or %status% = 6 &then &do
```

```
  &type Link Eliminated due to:
&end
&else &do
  &type  This Link is not Eliminated
&end
&messages &on

&return
```

```
/*  explan.aml
/*  To explain the reason for the elimination of the link.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : .curr_cov, link#, idel, funit, iwrt, icls


/*  IDENTIFY FUNCTION IN ARCPLOT
clearselect
reselect %.curr_cov% arcs one *
&s link# = [show select %.curr_cov% line 1 item %.curr_cov%#]
&if [exists ~arvind/demo/link_checked.txt -file] &then
&s idel = [delete ~arvind/demo/link_checked.txt -file]
&s funit = [open ~arvind/demo/link_checked.txt openstatus -write]
&s iwrt = [write %funit% %link#%]
&s icls = [close %funit%]
&sys xterm -e ~arvind/demo/Expl &
&return
```

```
/*  reject.aml
/*  Rejects the inference on elimination.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
Arguments : .id, roption


clearselect
&messages &popup
&type Select Link
&messages &on

/*  SELECT LINK AND EXTRACT ID
reselect fl103 arc one *
&s id = [show select fl103 arc 1 item fl103#]
reselect fl103.aat info fl103# = %id%

/*  SYMBOL AND UPDATE IMPEDANCE ACCORDING TO RESPONSE
&messages &popup
&s roption = [response 'Reset Status - Eliminate/Use']

&if [quote [upcase %roption%]] cn 'ELIMINATE' &then &do
  calculate %.curr_cov%.aat info tempsym = 11
  calculate %.curr_cov%.aat info from_to_imp = 1000000
  calculate %.curr_cov%.aat info to_from_imp = 1000000
```

```
  &type Link Closed, Redrawing Map
&end
&else &do
  calculate %.curr_cov%.aat info tempsym = permsym
  calculate %.curr_cov%.aat info from_to_imp = perm_frtimp
  calculate %.curr_cov%.aat info to_from_imp = perm_tofimp
  &type Link Opened, Redrawing Map
&end
&messages &on

clearselect
clear
arclines fl103 tempsym
&return
```

```
/*  rt_gen.aml
/*  To find the shortest path between a specified node pair after link
/*  elimination.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


clearsel;
netcover %.curr_cov% dynart init;
impedance from_to_imp to_from_imp
searchtolerance automatic;

/*  INTERACTIVELY SELECT NODES
&messages &popup;
&type any key to enter point, 9 to exit
&messages &on;

path *;

/*  DISPLAY SHORTEST PATH
routelines %.curr_cov% dynart 14;
&return;
```

```
/*  rt_prio.aml
/*  Prioritization of diversion routes (Still under construction).
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


/*  POPUP A MESSAGE SHOWING FUTURE IMPLEMENTATION
&messages &popup
&type To be Implemented
&messages &on
&return
```

```
/*  bcastmes_statrt.aml
/*  Sends messages back to involved groups indicating poa. Message
/*  content fixed at present. Broadcasts message to use stat_rtplan.
/*  Presently informs the police control center to use the static route
/*  plan.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June. 95
/*  Project :  Incident Management
/*  Arguments : status


&s pol_server [IACCONNECT pol_cf status]
/* &s tmc_req [IACREQUEST %pol_server% 1 '&r polaml/statrt_mess.aml'
status]
&s tmc_req [IACREQUEST %pol_server% 1 '&messages &popup' status]
&s tmc_req [IACREQUEST %pol_server% 1 '&ty Use Static Route Plan for
Diversion' status]
&s tmc_req [IACREQUEST %pol_server% 1 '&messages &on' status]
&s status = [IACDISCONNECT %pol_server%]
&return
```

```
/*  bcastmes_dynart.aml
/*  Sends messages back to involved groups indicating poa. Message
/*  content fixed at present. Broadcasts message to use dynart_rtplan.
/*  Presently informs the police control center to use the dynamic
/*  route plan.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June. 95
/*  Project :  Incident Management
/*  Arguments : status

&s pol_server [IACCONNECT pol_cf status]
/* &s tmc_req [IACREQUEST %pol_server% 1 '&r polaml/dynart_mess.aml'
status]
&s tmc_req [IACREQUEST %pol_server% 1 '&messages &popup' status]
&s tmc_req [IACREQUEST %pol_server% 1 '&ty Use Dynamic Route Plan for
Diversion' status]
&s tmc_req [IACREQUEST %pol_server% 1 '&messages &on' status]
&s status = [IACDISCONNECT %pol_server%]
&return
```

```
/*  init.aml
/*  Initializes symbols in tempsym and resets impedances select the
/*  links that have been eliminated or are the incident links. These
/*  would have tempsym = 11(eliminated) or 13(incident link).
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


clearselect
reselect %.curr_cov%.aat info tempsym = 11
```

```
aselect %.curr_cov%.aat info tempsym = 13

calculate %.curr_cov%.aat info TEMPSYM = PERMSYM
calculate %.curr_cov%.aat info from_to_imp = perm_frtimp
calculate %.curr_cov%.aat info to_from_imp = perm_tofimp

clearsel
&return
```

C.
ARCEDIT AMLS

```
/*  edit_ses.menu
/*  Creates the edit session pulldown menu
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


1
Feature
   Network    &run tmcaml/disp_ae.aml
   Route      &run tmcaml/draw_rt.aml

View
   'Zoom In'    &run tmcaml/aezi
   'Zoom Out'   &run tmcaml/aezo
    Pan         &run tmcaml/aepan
   'Full View'  &run tmcaml/aefullvi
'Diversion Route'
   'Select Links'        &run tmcaml/sel_lnk.aml
   'Remove Links'        &run tmcaml/rem_lnk.aml
   'Add Links'           &run tmcaml/add_lnk.aml
   'Make Route'          &run tmcaml/mak_rt.aml
   'Append Sections'     &run tmcaml/app_sec.aml
   'Remove Sections'     &run tmcaml/rem_sec.aml
   'Delete Route'        &run tmcaml/del_rt.aml
'Road System'
   'Select Links(mouse)'  &run tmcaml/sel_lnk.aml
   'Select Links(name)'   &run tmcaml/sel_lnk_nm.aml
   'Remove Links'         &run tmcaml/rem_lnk.aml
   'Add Links(mouse)'     &run tmcaml/add_lnk.aml
   'Add Links(name)'      &run tmcaml/add_lnk_nm.aml
   'Make Route'           &run tmcaml/mak_rd.aml
   'Append Sections'      &run tmcaml/app_sec_rd.aml
   'Remove Sections'      &run tmcaml/rem_sec_rd.aml
   'Delete Route'         &run tmcaml/del_rd.aml
'Point Event'
   'Select Route'  &run tmcaml/sel_rt.aml
   'Add Event'     &run tmcaml/add_evt.aml
   'Remove Event'  &run tmcaml/rem_evt.aml
   'Wrap-up'       &run tmcaml/rap_evt.aml
'Link Attribute'
   'Select(mouse)'  &run tmcaml/sel_lnk.aml
   'Select(id)'     &run tmcaml/sel_lnk_id
   'Remove links'   &run tmcaml/rem_lnk.aml
   'Add Links'      &run tmcaml/add_lnk.aml
   'Assign St_Rt'   &run tmcaml/ass_strt.aml
   'Assign Id'      &run tmcaml/ass_id.aml
   'Assign Others'  &run tmcaml/ass_others
Keyboard           &tty
Clear
```

```
'Session'
   'Save Edits'                &run tmcaml/sav_cov.aml
   'Discard Edits and Quit'    &run tmcaml/dis_quit.aml
   'Save Edits and Quit'       &run tmcaml/sav_quit.aml
```

```
/*  disp_ae.aml
/*  To display the features in the coverage for editing.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


mape  %.curr_cov%
editcov  %.curr_cov%
editf arc
drawe arc
draw
&return
```

```
/*  draw_rt.aml
/*  Draws the route during the edit session.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


drawe route.histrt arrows
draw
&return
```

```
/*  zi.aml
/*  Zoom in repeatedly around specified points
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : mx, .xlow, .xlow, .xhigh, .yhigh, .dx, .dy


&messages &popup
&fullscreen &popup
&type any key to zoom in, 9 to exit
&messages &on
&fullscreen &on
&label top
&getp &current
&if %pnt$key% = 9 &then &return
&type zooming in...

/*  EXTRACT THE MAPEXTENT COORDINATES
&s mx = [show mapextent]
&s .xlow  = [extract 1 %mx%]
&s .ylow  = [extract 2 %mx%]
```

```
&s .xhigh = [extract 3 %mx%]
&s .yhigh = [extract 4 %mx%]
&s .dx = %.xhigh% - %.xlow%
&s .dy = %.yhigh% - %.ylow%

/*  ADJUST MAPEXTENT WITH THE SPECIFIED POINT AS THE
/*  CENTER OF HALF THE ORIGINAL EXTENT
&s .xl %pnt$x% - %.dx% / 4
&s .yl %pnt$y% - %.dy% / 4
&s .xh %pnt$x% + %.dx% / 4
&s .yh %pnt$y% + %.dy% / 4

/*DEFINE NEW  MAPEXTENT AND REDRAW ARCS
mapextent %.xl% %.yl% %.xh% %.yh%
clear
draw
&goto top
```

```
/*  zo.aml
/*  Zoom out repeatedly around specified points
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : mx, .xlow, .xlow, .xhigh, .yhigh, .dx, .dy


&messages &popup
&fullscreen &popup
&type any key to zoom out, 9 to exit
&messages &on
&fullscreen &on
&label top
&getp &current
&if %pnt$key% = 9 &then &return
&type zooming out...

/*  EXTRACT THE MAPEXTENT COORDINATES
&s mx = [show mapextent]
&s .xlow  = [extract 1 %mx%]
&s .ylow  = [extract 2 %mx%]
&s .xhigh = [extract 3 %mx%]
&s .yhigh = [extract 4 %mx%]
&s .dx = %.xhigh% - %.xlow%
&s .dy = %.yhigh% - %.ylow%

/*  ADJUST MAPEXTENT WITH THE SPECIFIED POINT AS THE
/*  CENTER OF TWICE THE ORIGINAL EXTENT
&s .xl %pnt$x% - %.dx%
&s .yl %pnt$y% - %.dy%
&s .xh %pnt$x% + %.dx%
&s .yh %pnt$y% + %.dy%

/*DEFINE NEW MAPEXTENT AND REDRAW ARCS
mapextent %.xl% %.yl% %.xh% %.yh%
clear
drawe arc
```

```
draw
&goto top
```

```
/*  pan.aml
/*  To pan across a coverage using the software mapextent
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : mx, .xlow, .xlow, .xhigh, .yhigh, .dx, .dy


&messages &popup
&fullscreen &popup
&type any key to pan, 9 to exit
&messages &on
&fullscreen &on
&label top
&getp &current
&if %pnt$key% = 9 &then &return
&type panning...

/*  EXTRACT THE MAPEXTENT COORDINATES
&s mx = [show mapextent]
&s .xlow  = [extract 1 %mx%]
&s .ylow  = [extract 2 %mx%]
&s .xhigh = [extract 3 %mx%]
&s .yhigh = [extract 4 %mx%]
&s .dx = %.xhigh% - %.xlow%
&s .dy = %.yhigh% - %.ylow%

/*  ADJUST MAPEXTENT TO MAKE THE SPECIFIED POINT THE
/*  CENTER OF THE EXTENT
&s dx2 %.dx% / 2
&s dy2 %.dy% / 2
&s .xl %pnt$x% - %dx2%
&s .xh %pnt$x% + %dx2%
&s .yl %pnt$y% - %dy2%
&s .yh %pnt$y% + %dy2%

/*  DEFINE NEW MAPEXTENT AND REDRAW ARCS
clear
mapextent %.xl% %.yl% %.xh% %.yh%
drawe arc
draw
&goto top
```

```
/*  fullvi.aml
/*  Displays the selected features for entire coverage
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


select all
```

```
mape  %.curr_cov%
clear
drawe arc
draw
&return
```

```
/*  sel_lnk.aml
/*  Selects links in the route system.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


select many
&return
```

```
/*  rem_lnk.aml
/*  Remove links from the selected route set .
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


unselect many
&return
```

```
/*  add_lnk.aml
/*  Adds links to the currently selected set for a route system
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


aselect many
&return
```

```
/*  mak_rt.aml
/*  Makes the currently selected set of links as a route set.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : curr_rtnrm, .rt_id, prio


&messages &popup
&s curr_rtnm = [response 'Enter the Route Name']
&messages &on
&s curr_rtnm = [upcase [value curr_rtnm]]
```

```
&s .rt_id = [translate [value curr_rtnm] 1234 ENWS]
&s prio = [quote [getchoice UL UR LL LR -prompt 'Origin:']]
makeroute  HISTRT  %.rt_id% length [unquote %prio%] START 0
ef route.histrt
sel HISTRT-ID = %.rt_id%
calculate name = [quote %curr_rtnm%]
ef arc
&return
```

```
/*  app_sec.aml
/*  Macros for appending route fragment to a just-built route. This is
/*  useful in contruction routes containing loops
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : sel HISTRT-ID


ef route.histrt
sel HISTRT-ID = %.rt_id%

append arc many
remeasure route_himeas route_himeas

ef arc
&return
```

```
/*  rem_sec.aml
/*  Remove links from the selected route set.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


unselect many
&return
```

```
/*  del_rt.aml
/*  Macro for deleting an existing route in histrt.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : name, del_rt_nm


&messages &popup
&s del_rt_nm = [quote [upcase [response 'Enter the Route Name']]]
&messages &on
edit fairfax route.histrt
sel name = %del_rt_nm%
delete

edit %.curr_cov%
```

```
ef arc
&return
```

```
/*  sel_lnk.aml
/*  Selects links in the route system.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


select many
&return
```

```
/*  sel_lnk_nm.aml
/*  selects links by name.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : lnk_nm


&messages &popup
&s lnk_nm = [response 'Enter the link name']
&messages &on
&s lnk_nm  = [upcase [value lnk_nm]]
select NAME = %lnk_nm%
&return
```

```
/*  rem_lnk.aml
/*  Remove links from the selected route set.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


unselect many
&return
```

```
/*  add_lnk.aml
/*  Adds links to the currently selected set for a route system.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


aselect many
&return
```

```
/*  add_lnk_nm.aml
/*  adds links by name.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : lnk_nm


&messages &popup
&s lnk_nm = [response 'Enter the link name']
&messages &on
&s lnk_nm  = [upcase [value lnk_nm]]
aselect NAME = %lnk_nm%
&return
```

```
/*  sel_rt.aml
/*  Prompts user for the name of the route for which the events are
/*  being created and retreives the value of the histrt#.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : st_rt, int_rt_no, .rt_id#


editf route.histrt
&messages &popup
&s st_rt_nm = [quote [upcase [response 'Enter the Route Name']]]
&messages &on
SEL NAME = %st_rt_nm%
&s int_rt_no = [show select 1]
&s .rt_id# = [show route.histrt %int_rt_no% item histrt#]
&return
```

```
/*  add_evt.aml
/*  Macro for adding events to the event table fairfax.events. Needs the
/*  input from the sel_rt.aml the value of the histrt# (global) and
/*  calculates the measure for each specified event point and writes
/*  them to fairfax.events. Also requests user for event-id and type.
/*  Calls arcplot with add_event_arcplot.aml as argument to calculate
/*  measures.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments :  evt_no chosen_type


&messages &popup
&label top
&s evt_no = [response 'Enter the event ID.']
&s chosen_type = [quote [getchoice POLICE VMS TRAF_LIGHT DET_SIGN -
PROMPT 'Choose a Type']]
&messages &on
arcplot tmcaml/add_event_arcplot.aml
```

```
&if %.measure% = 0 &then &goto top
edit %.curr_cov%.events info
add
calculate ffx_eve-id = %evt_no%
calculate histrt# = %.rt_id#%
calculate measure = %.measure%
calculate type = %chosen_type%

&return
```

```
/*  rev_evt.aml
/*  Macros for removing event from coverage.events.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


&messages &popup
&s event-id = [response 'Enter event ID.']
&messages &on
edit fairfax.events info
sel ffx_eve-id = %event-id%
delete
&return
```

```
/*  rap_evt.aml
/*  Macros for wrapping up the event input for a single route.
/*  Actually, it sets up the environment for the next route.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


edit %.curr_cov%
&return
```

```
/*  sel_lnk.aml
/*  Selects links in the route system.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


select many
&return
```

```
/*  sel_lnk_id.aml
/*  Select link using link ID.
/*  Written by :  Srikanth Jonnalagadda
```

```
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : id


ef arc
&messages &popup
&s id  = [response 'Enter the id']
&messages &on
select id = %id%
&return
```

```
/*  rem_lnk.aml
/*  Remove links from the selected route set.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


unselect many
&return
```

```
/*  add_lnk.aml
/*  Adds links to the currently selected set for a route system.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


aselect many
&return
```

```
/*  ass_strt.aml
/*  This aml gets the route no. and then assigns it to the selected
/*  links as stat_rtno in the aat file.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : st_rt_na


&messages &popup
&s st_rt_na = [response 'Enter the Route Name']
&messages &on
&s st_rt_na = [quote [upcase [value st_rt_na]]]
calculate STAT_RTNM = %st_rt_na%
&return
```

```
/*  ass_id.aml
/*  Assigns the user-inputted route ID to selected links as stat_rtno in
/*  aat file.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : id


&messages &popup
&s id  = [response 'Enter the id']
&messages &on
calculate id = %id%
&return
```

```
/*  ass_other.aml
/*  Assigns other variables like hs_volan, caplan etc. for the route.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : vol, cap, spd


&messages &popup
&fullscreen &popup
&s vol = [response 'Enter the new volume']
&s cap = [response 'Enter the new capacity']
&s spd = [response 'Enter the new maximum speed']
calculate  hs_volan =  %vol%
calculate  caplan =  %cap%
calculate  max_spd =  %spd%
&messages &on
&fullscreen &on
&return
```

```
/*  sav_cov.aml
/*  Saves the currently used coverage and info files in arcedit session.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


save all y
edit %.curr_cov%
ef arc
&return
```

```
/*  dis_quit.aml
/*  Discard edits and quit arcedit session.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
```

```
/*  Project :  Incident Management
/*  Arguments : none


quit
n
q
```

```
/*  sav_quit.aml
/*  Saves the edits and leaves ARCEDIT session.
/*  Written by :  Srikanth Jonnalagadda
/*  Last Update Date : June 95
/*  Project :  Incident Management
/*  Arguments : none


save
quit
quit
```

D.
ARC-NEXPERT BRIDGE ROUTINES

```
/*arc_retrieve.c

  Program called during the link elimination operation to read/write link
  attributes from the info files and call the nexpert link elimination
  function to decide on elimination status of links.  Accordingly modify
  the display symbol in the COVERAGE.AAT so as to reflect changes when
  the display is updated.

  Last Updated by Srikanth on Feb. 10, 1995

  Comments:Final executable created - Netgen
           arc_retrieve.o and infolib.a as dependencies

  Future:Will need to change the part on reading the link attribute 'CLASS'
         Currently don't have the rules for using this item.  Only set bridge
         or not bridge.
*/

#include <stdio.h>
#include <stdlib.h>
#include "/home/srikanth/infoc/bin/infolib/infolib.h"
#include "/home/srikanth/infoc/bin/infolib/infodefs.h"

#define REQUIRED_NUMBER_OF_ARGUMENTS 4
#define ORIG_COV_IDITEM "FAIRFAX#"
#define ELIM_SYMBOL 11

#define USAGE "usage: retreive <record number> <Info File Name Path>"
#define FatalError( mess ) { fprintf(stderr,"%s\n",mess);\
        fprintf(stdout,"&s .INFOStatus := .false.\n"); exit(0); }

int      ELIMINATION_STATUS_FOR_LINK;
int      ARC_LENGTH;;
int      ARC_LINK_VOLUME;
int      ARC_LINK_CAPACITY;
char     ARC_LINK_TYPE_DESC_STRING[30];
char     ARC_LINK_ICE_SNOW_CLEARANCE[30];
float    ARC_LINK_TRAF_VOLUME;
float    ARC_LINK_SPEED_LIMIT;
char     ARC_LINK_CLASS;
int      ARC_N_LANES;

/*main
  Calls read_all_record_values to read link attributes from the subset info
  file (SUBSET.AAT) created in ARC.  SUBSET.AAT contains arcs that lie in
  the search/impact area for a given incident.

  Subsequently calls main_link_elimination_program to decide on elimination
  status for each link in the subset file.  Based on the the elimination
  status, directly updates the item - TEMPSYM in the COVERAGE.AAT with the
  symbol for eliminated links - 11 (ELIM_SYMBOL)

  Also calls main_incident_window to allow user to input additional details
  about the incident.
```

```
  Arguments:  executable, record number to access, filepath for COVERAGE.AAT
              filepath for SUBSET.AAT
*/

main(int argc, char  **argv)
{

char                 *InfoFileMainPath; /* Path for COVERAGE.AAT*/
char                 *InfoFilePath;     /* Path for SUBSET.AAT*/
InfoFile             *InfoFilePtr;      /* Pointer to the SUBSET.AAT*/
InfoFile             *InfoFileMainPtr;  /* Pointer to the COVERAGE.AAT*/
int                  M_Record_Number;
char                 temp_string_1[20];
char                 temp_string_2[20];
char                 temp_string_3[20];
int                  temp_int;
int                  i;

InfoItemDef          *my_itemdefptr;
double               temp_length;
int                  symbol;
InfoItemDef          *my_itemdefptr_1;
int                  ARC_IS_LINK_BRIDGE;
int                  int_spd_max;
double               temp_double;
int                  original_record_no;

/* STELLHORNS FUNCTION to read an info record */
short int mf_InfoReadRecord( InfoFile *ifp, long int recno );

/*This function reads all attributes for one link*/
int read_all_record_values(InfoFile *InfoFilePtr, int i);

/*This functions opens a window for user input on addtional incdent chars*/
extern int  main_incident_window();

/*This function sets the ELIMINATION_STATUS_FOR_LINK.*/
extern void main_link_elimination_program();


if(argc!=REQUIRED_NUMBER_OF_ARGUMENTS) FatalError(USAGE);
puts(argv[1]);

sscanf(argv[1],"%d",&M_Record_Number);
InfoFileMainPath = argv[2];
InfoFilePath   = argv[3];

puts(InfoFilePath);  /*Echo to check*/
printf("\n");

if((InfoFilePtr = InfoOpenFile(InfoFilePath,InfoWRITE))== (InfoFile *)NULL)
FatalError(USAGE);
if((InfoFileMainPtr = InfoOpenFile(InfoFileMainPath,InfoWRITE))== (InfoFile
*)NULL) FatalError(USAGE);

/*Call user interface to input additional incident charactersitcs required
  to decompose network*/
main_incident_window();

for(i=1;i<=InfoNumberRecords(InfoFilePtr);i++)
  {
  /*this loop is run for the number of records in the subset file */
```

```
  ELIMINATION_STATUS_FOR_LINK = 0; /*initialization for each link;*/
  if(!read_all_record_values(InfoFilePtr,i))
    {
    printf("\nERROR READING INFO DATA for link %d \nEXITING PROGRAM.",i);
    }
  main_link_elimination_program();  /* transfer to nexpert here */
  if(ELIMINATION_STATUS_FOR_LINK == 1)
    {
    /*This part is executed if the expert system decides that the link
      should not be used for diversion*/

     my_itemdefptr   = InfoGetItemDef(InfoFilePtr,ORIG_COV_IDITEM);
     /*my_itemdefptr now points to the item in the subset.aat that references
       the record number of that link in the main coverage*/

     InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
     original_record_no = (int) temp_double;
     printf("\noriginal rec no:%d", original_record_no);
     /*Now have the original record number in the COVERAGE.AAT*/

     if(InfoReadRecord(InfoFileMainPtr, original_record_no)!=INFO_SUCCESS) {
printf("\n error in Reading Record"); exit (0); }
     my_itemdefptr_1 = InfoGetItemDef(InfoFileMainPtr,"TEMPSYM");
     /*Set the color code for eliminated links in COVERAGE.AAT*/

     symbol = ELIM_SYMBOL;
     InfoEncode(InfoFileMainPtr,my_itemdefptr_1,temp_string_1,(double) symbol);
     InfoWriteRecord(InfoFileMainPtr,original_record_no);
     /*for display the link now has the color for an eliminated link - red*/
    }
  }

InfoCloseFile(InfoFilePtr);
InfoCloseFile(InfoFileMainPtr);
printf("\n Updating the Map Display ....\n");
printf("\n Eliminated Links in Red ....\n ");

}


int read_all_record_values(InfoFile *InfoFilePtr, int i)
{

/*This function reads each record in the info file pointed to by the InfoFilePtr
and is called by the main program before calling the expert system for link
elimination.  The values read are written into global variables defined in this
file. These variables are accessed as extern by the nexpert-api functions to
transfer variables to the expert system shell
*/

InfoItemDef  *my_itemdefptr;
int     ARC_IS_LINK_BRIDGE;
int     int_spd_max;
char    temp_string_1[30];
double  temp_double;

my_itemdefptr = InfoGetItemDef(InfoFilePtr,"LENGTH");
if(InfoReadRecord(InfoFilePtr, i)!=INFO_SUCCESS) { printf("\n error in Reading
Record"); exit (0); }

InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
ARC_LENGTH = temp_double;
```

```
my_itemdefptr = InfoGetItemDef(InfoFilePtr,"HS_VOLAN");
InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
ARC_LINK_VOLUME = temp_double;

my_itemdefptr = InfoGetItemDef(InfoFilePtr,"N_LANES");
InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
ARC_N_LANES = temp_double;
ARC_LINK_VOLUME = ARC_LINK_VOLUME*ARC_N_LANES;

my_itemdefptr = InfoGetItemDef(InfoFilePtr,"CAPLAN");
InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
ARC_LINK_CAPACITY = temp_double;
ARC_LINK_CAPACITY = ARC_LINK_CAPACITY*ARC_N_LANES;

my_itemdefptr = InfoGetItemDef(InfoFilePtr,"BRIDGE");
InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
ARC_IS_LINK_BRIDGE = temp_double;

if(ARC_IS_LINK_BRIDGE)  /*Presence of bridge indicated by 0/1 flag*/
  {
  strcpy(ARC_LINK_TYPE_DESC_STRING,"Bridge");
  }
  else
  {
  my_itemdefptr = InfoGetItemDef(InfoFilePtr,"CLASS");
  InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
  ARC_LINK_CLASS = temp_string_1[0];

  /*At the present stage of implementation, only need to classify as
    bridge/not bridge. Reading class as of now is not necessary but will
    be needed as and when the nexpert rules using class are written*/

  strcpy(ARC_LINK_TYPE_DESC_STRING,"NOT BRIDGE");
  }

/*ARC link ice snow clearance is now set to unknown.  Attribute not
  yet maintained as an info item.  Will be added to the AAT when the
  data is available (??).
*/

strcpy(ARC_LINK_ICE_SNOW_CLEARANCE,"NOTKNOWN");

my_itemdefptr = InfoGetItemDef(InfoFilePtr,"MAX_SPD");
InfoDecode(InfoFilePtr, my_itemdefptr, temp_string_1, &temp_double);
ARC_LINK_SPEED_LIMIT = temp_double;
```

VITA

Srikanth Jonnalagadda was born on 5 January,1971 in Samalkot, India. He joined the Indian Institute of Technology, Madras in 1989 for a Bachelors in Civil Engineering. He graduated in July, 1993. In August, 1993 he joined the Department of Civil Engineering at Virginia Polytechnic Institute & State University, for a Master's in Transportation Engineering. He currently work with Innovative System Developers, Inc., a GIS leading implementation and services company.